BIRDSEYE VIEW OF IRONWOOD, 1886

PROCEEDINGS

OF THE

Lake Superior Mining Institute

FIFTEENTH ANNUAL MEETING

GOGEBIC RANGE, MICHIGAN

AUGUST 24, 25, 26, 1910

VOL. XV.

ISHPEMING, MICH.
PUBLISHED BY THE INSTITUTE
AT THE OFFICE OF THE SECRETARY
1910

PRESSES OF IRON ORE
ISHPEMING, MICH.

INDEX—VOL. XV.

INDEX TO PAPERS.

ILLUSTRATIONS AND MAPS.

INDEX TO BIOGRAPHICAL NOTICES.

OFFICERS

For the Year Ending August, 1910.

PRESIDENT.

D. E. SUTHERLAND................................Ironwood, Mich.
(Term one year.)

VICE-PRESIDENTS.

WILLIAM J. RICHARDS.........................Crystal Falls, Mich.
CHARLES TREZONA ....Ely, Minn.
(Term expires 1910.)

JOHN M. BUSH..Ironwood, Mich.
FREDERICK W. SPERR ....Houghton, Mich.
JAMES H. ROUGH...................................Ishpeming, Mich.
(Term expires 1911.)

MANAGERS.

FRANK E. KEESE..................................Ishpeming, Mich.
WILLIAM J. UREN...................................Calumet, Mich.
L. M. HARDENBURG...................................Hurley, Wis.
(Term expires 1910.)

CHARLES E. LAWRENCE....................Iron Mountain, Mich.
WILLIAM J. WEST..................................Hibbing, Minn.
(Term expires 1911.)

TREASURER.

E. W. Hopkins.................................Commonwealth, Wis.
(Term expires 1910.)

SECRETARY.

A. J. YUNGBLUTH...............................Ishpeming, Mich,
(Term expires 1910.)

OFFICERS

For the Year Ending 1911.

The following is list of officers elected at the annual meeting August 26th, 1910, also the officers holding over from the previous year and which are indicated by *:

PRESIDENT.

W. J. RICHARDS................................Crystal Falls, Mich.
(Term one year.)

VICE-PRESIDENTS.

*JOHN M. BUSH ....Ironwood, Mich.
*FREDERICK W. SPERR ....Houghton, Mich.
*JAMES H. ROUGH ....Negaunee, Mich.
(Term expires 1911).

E. D. BRIGHAM ....Chicago, Ills.
C. H. MUNGER.....................................Duluth, Minn.
(Term expires 1912.)

MANAGERS.

*CHARLES E. LAWRENCE ....Iron Mountain, Mich.
*WILLIAM J. WEST ....Hibbing, Minn.
(Term expires 1911.)

PETER PASCOE ....Republic, Mich.
J. B. COOPER ....Hubbell, Mich.
L. C. BREWER.....................................Ironwood, Mich.
(Term expires 1912.)

TREASURER.

E. W. HOPKINS.............................Commonwealth, Wis.
(Term expires 1911.)

SECRETARY.

A. J. YUNGBLUTH...............................Ishpeming, Mich.
(Term expires 1911.)

MEMBERS OF THE INSTITUTE, 1910.

HONORARY MEMBERS.

DOUGLAS, JAMES ....99 John St., New York City.
POMPELLY, RAPHAEL ....Dublin, N. H.
VAN HISE, C. R....................................Madison, Wis.
WINCHELL, N. H. ....501 East River Road, Minneapolis, Minn.

LIFE MEMBERS.

KELLY, WILLIAM ....Vulcan, Mich.
SILLIMAN, A. P... ....Hibbing, Minn.

ACTIVE MEMBERS.

ABBOTT, C. E.......................................Bessemer, Ala.
ABEEL, GEORGE H.................................Hurley, Wis.
ABEEL, GEO. H., JR..............................Wakefield, Mich.
ABELL, OLIVER J..................Old Colony Bldg., Chicago, Ills.
ADAMS, DAVID T...............503 Providence Bldg., Duluth, Minn.
ADAMS, JOHN B...................................Duluth, Minn.
ADAMS, JOHN Q...............................Negaunee, Mich.
ADGATE, FREDERICK W..........419 Rookery Bldg., Chicago, Ills.
AISHTON, R. H....................215 Jackson Blvd., Chicago, Ills.
ALLEN, R. C.......................................Lansing, Mich.
ALVER, G. A.......................................Norway, Mich.
AMBERG, J. W.......................1400 Fulton St., Chicago, Ills.
AMBERG, WILLIAM A...............1400 Fulton St., Chicago, Ills.
ANDERSON, G. A................................Deerwood, Minn.
ANGST, ROBERT A..............................Hibbing, Minn.
APPLEBY, WILLIAM R.........School of Mines, Minneapolis, Minn.
ARMSTRONG, FRANK H...........................Vulcan, Mich.

BAER, HENRY L..................................Hancock, Mich.
BAIRD, ALEXANDER ....1010 Fisher Bldg., Chicago, Ills.
BALDWIN, C. KEMBLE.........1070 Old Colony Bldg., Chicago, Ills.

BALL, EDWIN ....Birmingham, Ala.
BANDLER, ARTHUR S...............65 Nausau St., New York City.
BARABI, C. A....................................Ishpeming, Mich.
BARBER, G. S....................................Bessemer, Mich.
BARBER, MAX H...................................Ishpeming, Mich.
BARR, H. A......................................Escanaba, Mich.
BARROWS, WALTER A., JR....1183 E. Boulevard, Cleveland, Ohio.
BAXTER, CHARLES HOMER...........................Loretto, Mich.
BELDEN, WILLIAM P...............................Ishpeming, Mich.
BENGRY, WILLIAM H...............................Palatka, Mich.
BENNETT, R. M........710 Security Bank Bldg., Minneapolis, Minn.
BENSON, A. F....................................Virginia, Minn.
BEYENKA, THOMAS ....Houghton, Mich.
BINNY, JOSEPH ....McKinley, Minn.
BIRCKHEAD, LENNOX ....South Milwaukee, Wis.
BISCOMBE, JOSEPH R..............................Kearsarge, Mich.
BJORK, ARVID ....Crystal Falls, Mich.
BLACKWELL, FRANK ....Ironwood, Mich.
BLOOMFIELD, WALTER ....Hancock, Mich.
BOND, WILLIAM ....Ironwood, Mich.
BONE, ALFRED ....Ishpeming, Mich.
BONNELL, EVERETT S ....Douglas, Ariz.
BOWEN, REUBEN ....Box 311, New York City.
BRADT, E. F. ....151 Alexandrine Ave., West, Detroit, Mich.
BRADY, SAMUEL ....Rockland, Mich.
BREITUNG, EDWARD N.............................Marquette, Mich.
BRETT, HENRY ....Calumet, Mich.
BRETTING, C. G..................................Ashland, Wis.
BREWSTER, EDWARD E.....................Iron Mountain, Mich.
BREWER, CARL ....Ishpeming, Mich.
BREWER, LUTHER C................................Ironwood, Mich.
BRIGHAM, E. D....................215 Jackson Blvd., Chicago, Ills.
BRIGHAM, EDMOND D., JR..........................Chicago, Ills.
BROWN, JOHN JACOB ....Carteret, N. J.
BROWN, E. F............................Iron Mountain, Mich.
BROWNING, R. C.........................Iron Mountain, Mich.
BURR, FLOYD L...................................Vulcan, Mich.
BUSH, JOHN M....................................Ironwood, Mich.

CADDY, THOMAS ....Hibbing, Minn.
CAIRNS, FREDERICK I.............................Houghton, Mich.
CALVERLEY, W. D.................................Houghton, Mich.
CAMERON, ALLEN ....Calumet, Mich.
CAMPBELL, D. H..................................Iron River, Mich.
CARBIS, FRANK ....Iron Mountain, Mich.
CARMICHAEL, THOMAS ......853 2nd Ave., Salt Lake City, Utah.
CARMICHAEL, WILLIAM ....Biwabik, Minn.

CARNAHAN, ARTHUR L.........................Houghton, Mich.
CARPENTER, C. S................327 W. Superior St., Duluth, Minn.
CARR, GEORGE R..................McCormick Bldg., Chicago, Ills.
CARROL, MICHAEL J............................Houghton, Mich.
CARSON, JOHN A.................................Appleton, Wis.
CARTER, RAYMOND B.............224 Randolph St., Chicago, Ills.
CASTLE, WILLIAM B...............................Duluth, Minn.
CHADBOURNE, T. L.............................Houghton, Mich.
CHAMBERLAIN, PAUL FAIRFIELD ....Soudan, Minn.
CHAMBERS, DR. H. P............................Florence, Wis.
CHAMBERLIN, H. L. ....Michigamme, Mich.
CHAMPION, CHARLES ....Beacon, Mich.
CHAMPION, JOHN ....Loretto, Mich.
CHANNING, J. PARKE ....42 Broadway, New York City.
CHARLTON, WILLIAM H. ....Houghton, Mich.
CHASE, PHILO P. ....Ishpeming, Mich.
CHEYNEY, H. C. ....215 Jackson Blvd., Chicago, Ill.
CHINN, WILLIAM P. ....McKinley, Minn.
CHURCH, EDWARD ....Marquette, Mich.
CHYNOWETH, B. F.............................Houghton, Mich.
CHYNOWETH, JAMES ....Calumet, Mich.
CLANCEY, JAMES ....Ishpeming, Mich.
CLARK, HORACE S. ......1020 Commercial Bldg., Kansas City, Mo.
CLARK, KIMBALL ....Kimball, Wis.
CLEMENS, JOHN C. ....Ishpeming, Mich.
CLEMENTS, J. MORGAN ..Suite 1707, 42 Broadway, New York City.
CLIFFORD, J. M.................................Escanaba, Mich.
COGGIN, F. G.....................1508 Sheridan Road, Chicago, Ills.
COKEFAIR, FRANK A.............Providence Bldg., Duluth, Minn.
COLE, THOMAS F.................................Duluth, Minn.
COLE, WILLIAM T.............................Ishpeming, Mich.
COLE, CHARLES D............................Ishpeming, Mich.
COLE, WILLIAM A..............................Ironwood, Mich.
COLE, WILLIAM H..............713 Sellwood Bldg., Duluth, Minn.
COLEMAN, MILTON W..........................Virginia, Minn.
CONLIN, THOMAS ....Crystal Falls, Mich.
CONOVER, A. B.......................171 Lake St., Chicago, Ills.
CONNORS, THOMAS ....Negaunee, Mich.
COOPER, CLAUDE H............................Hancock, Mich.
COOPER, JAMES B..............................Hubbell, Mich.
COPELAND, FRANKLIN ....Vulcan, Mich.
COTTER, WILLIAM H.............65 Nausau St., New York City.
COVENTRY, F. L.................................Hibbing, Minn.
COYNE, WILLIAM ....Wilmington, Del.
CRAM, FRED W..............................Nashwauk, Minn.
CROSBY, GEO. H....................Lonsdale Bldg., Duluth, Minn.
CROWELL, BENEDICT ....Cleveland, Ohio.

CROXTON, DAVID T..............Rockefeller Bldg., Cleveland, Ohio.
CUMMINGS, GEORGE P...........................Marquette, Mich.
CUMMINGS, P. H..............................Ironwood, Mich.
CUNDY, H J.........................Iron Ridge, Dodge Co., Wis.
CURRY, SOLOMAN S............................Ironwood, Mich.
CURRY, GEORGE A.............................Ironwood, Mich.

DALTON, H. G................................Cleveland, Ohio.
DAMKROGER, H. C.............................Coleraine, Minn.
DAVEY, THOMAS H..............................Eveleth, Minn.
DAVIDSON, O. C.........................Iron Mountain, Mich.
DAVIDSON, WARD F.......................Iron Mountain, Mich.
DAVIS, W. J...................................Verona, Mich.
DAWE, PETER ....Calumet, Mich.
DEAN, DUDLEY S.....................87 Milk St., Boston, Mass.
DEE, JAMES R................................Houghton, Mich.
DEMMERT, HENRY ....12 John St., New York City.
DENTON, F. W...............................Painesdale, Mich.
DIEHL, G. E.....................607 Wolvin Bldg., Duluth, Minn.
DICKINSON, E. S..............................Florence, Wis.
DONOVAN, PERCY W.............................Brainerd, Minn.
DORMER, GEORGE H.............................Eveleth, Minn.
DOUGLAS, ROBERT A...........................Ironwood, Mich.
DRAKE, FRANK ....1845 Commercial Bank Bldg., Chicago, Ills.
DRAKE, ROLLIN E............................Ishpeming, Mich.
DRISCOLL, CORNELIUS B.......................Negaunee, Mich.
DUDLEY, HARRY C...............................Marble, Minn.
DUFF, HARRY E.............................Iron River, Mich.
DUNCAN, MURRAY M...........................Ishpeming, Mich.
DUNSTAN, ROBERT P............................Hancock, Mich.
DUNSTER, CARL B.............................Marquette, Mich.

EARLING, H. B...............................Milwaukee, Wis.
EATON, LUCIEN ....Ishpeming, Mich.
EDWARDS, A. D................................Atlantic, Mich.
EDWARDS, J. P.....................Mansfield, Iron Co., Mich.
EISELE, GEORGE J.......................Iron Mountain, Mich.
ELLARD, H. F.............San Antonio Copper Co., Sonora, Mexico.
ELLIOTT, MARK ....Virginia, Minn.
ELLIOTT, STUART R............................Negaunee, Mich.
ELLIS, JOHN ....Gwinn, Mich.
ERICKSON, CARL E.............................Ironwood, Mich.
ERICKSON, RUDOLPH ....Ishpeming, Mich.
ESSELSTYN, J. N............................Sugar Loaf, Colo.

FACKENTHAL, B. F., JR...............................Eaton, Pa.
FAIRBAIRN, CHARLES T............P. O. Box 859, Pittsburg, Pa.

FAIRCHILD, DAVID L............616 Lonsdale Bldg., Duluth, Minn.
FARRELL, AUSTIN ....Marquette, Mich.
FAY, JOSEPH ....Marquette, Mich.
FELCH, THEODORE A.............................Ishpeming, Mich.
FERGUSON, J. A..................316 W. Superior St., Duluth, Minn.
FESING, HERMAN W..............................Houghton, Mich.
FINDLEY, A. I...........Iron Age, 14 Park Place, New York City.
FISHER, JAMES, JR.............................Houghton, Mich.
FISHWICK, EDWARD F....60th & Greenfield Aves., Milwaukee, Wis.
FITCH, WALTER ....Eureka, Utah.
FLEWELLING, A. L................Columbia Bldg., Spokane, Wash.
FLODIN, NELS P................................Marquette, Mich.
FLOETER, A. H...................................Calumet, Mich.
FRASER, WILLIAM H.........................Crystal Falls, Mich.

GARDNER, W. A..................215 Jackson Blvd., Chicago, Ills.
GARNER, WILLIAM A.............................Negaunee, Mich.
GAY, JOSEPH E...................15 William St., New York City.
GETCHELL, FRANK H...............................Mohawk, Minn.
GHOLZ, ARTHUR L................................Hibbing, Minn.
GIBBS, GEORGE ....7th Ave. and 32nd St., New York City.
GIBSON, J. THOBURN...............................Amasa, Mich.
GILCHRIST, J. D...................1405 Downing St., Denver, Colo.
GILLILAND, WILLIAM M............................Douglas, Ariz.
GLASS, FRANK A.................................Brainerd, Minn.
GLENN, JOHN F..................................Saginaw, Mich.
GRABOWSKI, CHARLES ....Ely, Minn.
GRANT, B. F.....Concepcion del Oro, Apartado, 27 Zacatecas, Mexico.
GREENE, W. E...............4410 Franklin Ave., Cleveland, Ohio.
GREENWAY, JOHN C................................Warren, Ariz.
GODFREY, M. H.................................Coleraine, Minn.
GOODALE, G. S....................99 Blanche St. Houghton, Mich.
GOODELL, H. S.................................Painesdale, Mich.
GOODMAN, FRANK B.................................Hurley, Wis.
GOODSELL, B. W...................20 S. Canal St., Chicago, Ills.
GORDON, ALEXANDER T.....................Mountain Iron, Minn.
GOUDIE, J. H...................................Ironwood, Mich.
GOUDIE, JAMES ....Ironwood, Mich.
GOW, ALEXANDER M..................Wolvin Bldg., Duluth, Minn.
GRAFF, W. W....................................Ishpeming, Mich.
GRIERSON, EDWARD S..............................Calumet, Mich.
GRIBBLE, SAMUEL J..............................Ironwood, Mich.

HAIRE, NORMAN W................................Houghton, Mich.
HAMMOND, THOMAS A.......................Crown Point, New York.
HAMPTON, CHARLES T.......................Iron Mountain, Mich.
HANNA, L. C...................................Cleveland, Ohio

HANSEN, W. G.......................................Palatka, Mich.
HARDEN, JAMES H...............Douglas House, Houghton, Mich.
HARDENBURG, L. M...............................Hurley, Wis.
HARRIS, H. R..Marquette, Mich.
HARRIS, JOHN L.....................................Hancock, Mich.
HARRIS, S. B..Hancock, Mich.
HARRIS, S. T..Houghton, Mich.
HARRISON, G. E......................................Hibbing, Minn.
HART, WILLIAM C...................................Hibbing, Minn.
HARTLEY, G. G..Duluth, Minn.
HARVEY, W. H...Eveleth, Minn.
HARWOOD, S. G......................Sherwood Bldg., Duluth, Minn.
HASELTON, H. S.....................................Cleveland, Ohio.
HAWKINS, M. S.................................Mountain Iron, Minn.
HEARDING, JOHN H..................................Duluth, Minn.
HEARLEY, MICHAEL T..............................Cleveland, Ohio.
HEATH, GEORGE L...................................Hubbell, Mich.
HEDIN, ANDREW G..................................Ironwood, Mich.
HEGGATON, WM. S..................................Negaunee, Mich.
HELPS, S. E..Eveleth, Minn.
HELLBERG, G. A......................................Norway, Mich.
HELMER, CHESTER E...............................Escanaba, Mich.
HENDRICK, C. E......................................Virginia, Minn.
HENDERSON, ENOCH................................Vicksburg, Ariz.
HEYN, HOWARD A...................................Ishpeming, Mich.
HICKOK, ELBERT E................137 E. Lake St., Chicago, Ills.
HICKS, B. W..Warren, Ills.
HILLYER, V. S..Ishpeming, Mich.
HILL, STACEY H.................Providence, Bldg., Duluth, Minn.
HINE, S. K...Girard, Ohio.
HITCHENS, JOHN H..........................Iron Mountain, Mich.
HOAR, SAMUEL ....Virginia, Minn.
HOBART, FREDERICK ....261 Broadway, New York City
HODGE, JOHN E......................................Marquette, Mich.
HODGE, RICHARD.....................................Hibbing Minn.
HODGSON, JOSEPH ....Ishpeming, Mich.
HODGSON, J. H.......................................Houghton, Mich.
HOLLEY, CARLOS E.................................Bessemer, Mich.
HOLLEY, A. B..Virginia, Minn.
HOLMAN, J. WINCHESTER....1420 Monadnock Bldg., Chicago, Ills.
HOLTERHOFF, A. B...........................Kearsarge P. O., Mich.
HOLTHOFF, HENRY C...............254 Nasau St., Milwaukee, Wis.
HONNOLD, W. L..............Box 2269 Johannesburg, South Africa.
HOOD, O. P...Houghton, Mich.
HOOSE, J. WILLIAM ....Iron Mountain, Mich.
HOPKINS, E. W...................................Commonwealth, Wis.
HOPKINS, HERMAN H., JR...........50 Dearborn St., Chicago, Ills.

HORE, R. E. . . . . .Houghton, Mich.
HOWE, GEORGE C. . . . . .2005 Blaisdell Ave., Minneapolis, Minn.
HOWE, GEO. T. . . . . .Ironwood, Mich.
HUBBARD, LUCIUS L. . . . . .Houghton, Mich.
HUGHES, CHARLES W. . . . . .Amasa, Mich.
HULST, HARRY T. . . . . .Ishpeming, Mich.
HULST, NELSON P. . . . . .300 Knapp St., Milwaukee, Wis.
HUNTER, ROY D. . . . . .1506 Railway Exchange Bldg., Chicago, Ills.
HUNNER, EARL E. . . . . .Wolvin Bldg., Duluth, Minn.
HURTER, CHAS. S. . . . . .314 Lyceum Bldg., Duluth, Minn.

IRELAND, JAMES D. . . . . .701 Sellwood Bldg., Duluth, Minn.

JACKA, JOSIAH S. . . . . .Crystal Falls, Mich.
JACKSON, GEORGE R. . . . . .Princeton, Mich.
JACKSON, J. F. . . . . .695 Colby-Abbot Bldg., Milwaukee, Wis.
JACKSON, FRANK W. . . . . .Market and Randolph Sts., Chicago, Ills.
JANSON, F. A. . . . . .Norway, Mich.
JENSON, N. C. . . . . .25 Broad St. N., New York City.
JETTNER, AUGUST R. . . . . .176 Randolph St., Chicago, Ills.
JEWELL, SAMUEL . . . . .Ishpeming, Mich.
JEWETT, FRANK . . . . .Hibbing, Minn.
JOBE, WILLIAM H. . . . . .Palatka, Mich.
JOHNS, ALEXANDER S. . . . . .Wakefield, Mich.
JOHNSON, EDWIN F. . . . . .Virginia, Minn.
JOHNSON, O. MARTIN. . . . . .Ishpeming, Mich.
JOHNSTON, WILLIAM H. . . . . .Ishpeming, Mich.
JONES, A. G. . . . . .Iron Mountain, Mich.
JONES, B. W. . . . . .Vulcan, Mich.
JONES, CHARLES C. . . . . .Ramsey, Mich.
JONES, E. W. . . . . .Norway, Mich.
JONES, JOHN T. . . . . .Iron Mountain, Mich.
JOPLING, ALFRED O. . . . . .Marquette, Mich.
JOPLING, JAMES E. . . . . .Ishpeming, Mich.
JOPLING, M. W. . . . . .Marquette, Mich.
JORY, WILLIAM. . . . . .Princeton, Mich.

KARKEET, J. H. . . . . .Iron Mountain, Mich.
KAUFMAN, HARRY L. . . . . .Marquette, Mich.
KEARNEY, F. H. . . . . .Ironwood, Mich.
KEESE, FRANK E. . . . . .Ishpeming, Mich.
KENNEDY, F. A. . . . . .Hibbing, Minn.
KING, ROBERT . . . . .Hurley, Wis.
KIRKPATRICK, J. CLARK. . . . . .Escanaba, Mich.
KLEFFMAN, JOHN . . . . .Hibbing, Minn.
KLINGLUND, F. D. . . . . .Stambaugh, Mich.
KNAPP, GEO F. . . . . .319 Rockefeller Bldg., Cleveland, Ohio.

KNIGHT, J. B....................................Norway, Mich.
KNIGHT, R. C....................................Eveleth, Minn.
KNIGHT, WILLIAM H...............................Bessemer, Mich.
KOCH, ARTHUR A..................................Houghton, Mich.
KOENIG, GEORGE A................................Houghton, Mich.
KOEPCKE, ALBERT F...............................Marquette, Mich.
KOEPEL, ED......................................Beacon Hill, Mich.
KRUSE, CHARLES T................................Ishpeming, Mich.

LADD, DAVID H...................................Wallaroo, South Australia.
LAMBRIX, MICHAEL................................Hurley, Wis.
LAMMARS, THEODORE L......820 So. Walnut St., Spokane, Wash.
LAMONT, JOHN D..................................Virginia, Minn.
LANE, ALFRED C..................................Tufts College, Mass.
LARSON, EDWARD..................................Florence, Wis.
LARSSON, PER....................................Striburg, Sweden.
LA RUE, WILLIAM G............208 Exchange Bldg., Duluth, Minn.
LASIER, F. G....................................Birmingham, Mich.
LATHAM, ARTHUR M................................Hibbing, Minn.
LAWRENCE, CHARLES E.............................Iron Mountain, Mich.
LAWTON, CHARLES L...............................Hancock, Mich.
LEIN. NELS......................................Eveleth, Minn.
LEOPOLD, N. F......................108 Dearborn St., Chicago, Ills.
LETZ, JOHN F.......................662 12th St., Milwaukee, Wis.
LIBBY, DR. E. M.................................Iron River, Mich.
LINDBERG, JOHN FREDERICK ....
LINN, A. E......................................Norway, Mich.
LINSLEY, W. B...................................Escanaba, Mich.
LONGYEAR, E. J........710 Security Bank Bldg., Minneapolis, Minn.
LONGYEAR, JOHN M................................Marquette, Mich.
LONSTORF, GEORGE J..........2301 Grand Ave., Milwaukee, Wis.
LOOK, WILLIAM F.................................Panama City, Fla.
LOOMIS, A. J....................................Hibbing, Minn.
LUKEY, FRANK....................................Hurley, Wis.
LUTES, J. S.....................................Biwabik, Minn.
LUXMORE, THOMAS L...............................Iron Mountain, Mich.
LYNCH, THOMAS F.................................Houghton, Mich.
LYTLE, ALEXANDER................................Norway, Mich.

MAAS, A. E.........................352 29th St., Milwaukee, Wis.
MAAS, GEORGE J..................................Negaunee, Mich.
MAAS, WILLIAM J.................................Negaunee, Mich.
MACE, ROBERT E....................Wolvin Bldg., Duluth, Minn.
MACDONALD, RONALD H.............................Dollar Bay, Mich.
MACNAUGHTON, JAMES..............................Calumet, Mich.
MACOMBER, F. B..................266 So. Clinton St., Chicago, Ills.
MANVILLE, T. F.................100 William St., New York City.

MARS, WILLIAM P....................................Duluth, Minn.
MARTIN, ALFRED ....Virginia, Minn.
MATHER, WILLIAM G..........Rockefeller, Bldg., Cleveland, Ohio.
MATTHEWS, WILLIAM C.........................Wilmington, Del.
MEAD, FRANK D...................................Escanaba, Mich.
MEADS, ALEXANDER P.......................Marquette, Mich.
MENNIE, JOHN S.................................Ishpeming, Mich.
MEUCHIE, A. H...................................Houghton, Mich.
MEYERS, WILLIAM R...........................Princeton, Mich.
MILLAR, JOHN M.................................Escanaba, Mich.
MILLER, A. M..........................215 Lyceum, Duluth, Minn.
MILLER, L. B........................Wade Bldg., Cleveland, Ohio.
MILLS, FRANK P............................Kimberley, Nevada.
MILLS, JOHN ....150 Lake St., Chicago, Ills.
MINER, ANSON B...............................Ishpeming, Mich.
MITCHELL, PENTECOST ....Duluth, Minn.
MITCHELL, R. J....................................Eveleth, Minn
MITCHELL, WILLIAM A.....16th and Rockwell Sts., Chicago, Ills.
MITCHELL, SAMUEL J..........................Marquette, Mich.
MOELLER, FRANKLIN ....Cleveland, Ohio.
MONROE, W. G.............................Iron Mountain, Mich.
MOORE, C. F...........920 Newhouse Bldg., Salt Lake City, Utah.
MOORE, CLARENCE E.............................Virginia, Minn.
MORGAN, DAVID T..............................Ishpeming, Mich.
MORRIS, CHARLES S.................2232 E. 1st St., Duluth, Minn.
MOULTON, W. H..................................Ishpeming, Mich
MOWATT, NEVILLE P........1432 McCormick Bldg., Chicago, Ills.
MUNGER, CHARLES H.............................Duluth, Minn.
MUNROE, HENRY S...........Columbia University, New York City.
MURPHY, C. M...................................Ishpeming, Mich.
MURRAY, ROBERT ....Hibbing, Minn.
M'CLURE, O. D...................................Ishpeming, Mich.
M'CURDY, WILLIAM A...................................Ely, Minn.
M'DONALD, D. B....................................Virginia, Minn.
M'DOWELL, JOHN ....Hibbing, Minn.
M'GEE, M. B....................................Crystal Falls, Mich.
M'GONAGLE, WILLIAM A...............Wolvin Bldg., Duluth, Minn.
M'GREGOR, SILAS J........................Iron Mountain, Mich.
M'CORMICK, EDWARD ....Buhl, Minn.
M'CORKINDALE, W. J.........................Ishpeming, Mich.
M'INDOE, JAMES A..................................Norway, Mich.
M'KEEVER, R. T...................82 Devonshire St., Boston, Mass.
M'KEE, WILL E.......................................Warren, Ariz.
M'LAUGHLIN, W. J..................................Loretto, Mich.
M'LEAN, JOHN H......................................Duluth, Minn.
M'LEAN, RICHARD EARLE.................Wells, Delta Co., Mich.
M'NAMARA, THOMAS B..........................Ironwood, Mich.

M'NAMARA, TIMOTHY .... Fierro, New Mexico.
M'NAIR, F. W .... Houghton, Mich.
M'NEIL, E. D .... Virginia, Minn.

NELSON, S. T .... 1170 W. Lake St., Chicago, Ills.
NEWETT, GEORGE A .... Ishpeming, Mich.
NEWTON, L. L .... 1324 La Salle Ave., Chicago, Ills.
NICHOLAS, THOMAS J .... Aurora, Minn.
NICHOLS, F. W .... Houghton, Mich.
NIXON, JOHN A .... Ishpeming, Mich.
NOBLE, THOMAS H .... Marquette, Mich.

OLCOTT, WILLIAM J .... Duluth, Minn.
ORBISON, THOMAS W .... Appleton, Wis.
ORR, FRANK D .... Exchange Bldg., Duluth, Minn.
OSBORN, CHASE S .... Sault Ste. Marie, Mich.

PALMER, E. V .... 308 McPhee Bldg., Denver, Colo.
PARKER, RICHARD A .... 404 Colorado Bldg., Denver, Colo.
PASCOE, PETER W .... Republic, Mich.
PASCOE, WILLIAM .... Hibbing, Minn.
PATRICK, RICHARD S .... 710 Torrey Bldg., Duluth, Minn.
PENTECOST, JOHN .... Calumet, Mich.
PENTON, JOHN A .... Iron Trade Review, Cleveland, Ohio.
PERKINS, SAMUEL J .... Ironwood, Mich.
PETERSON, JOHN O .... 921 Railroad Ave., Hancock, Mich.
PHILLIPS, W. G .... Calumet, Mich.
PIPER, JAMES .... Marquette, Mich.
PITKIN, S. H .... Akron, Ohio.
PLATTO, FRANK .... Ishpeming, Mich.
POLLOCK, CHARLES S .... Minneapolis, Minn.
POPE, GRAHAM .... Houghton, Mich.
POWELL, L. W .... Bisbee, Ariz.
POWELL, D. W .... Marquette, Mich.
PRESCOTT, FRED M .... Oregon St., Milwaukee, Wis.
PRESCOTT, L. L .... Menominee, Mich.
PRESHO, EDWARD W .... Houghton, Mich.
PRYOR, R. C .... Houghton, Mich.

QUIGLEY, G. J .... Antigo, Wis.
QUINE, JOHN THOMAS .... 413 Vine St., Ishpeming, Mich.
QUINN, CLEMENT KRUSE .... Virginia, Minn.

RAHT, CHARLES .... 56 Pine St., New York City.
RAISKY, F. H .... Ishpeming, Mich.
RALEY, ROBERT J .... Spalding Hotel, Duluth, Minn.
RASHLEIGH, WILLIAM J .... Aurora, Minn.

RATTLE, W. J..............33 Commercial Bldg., Cleveland, Ohio.
REDFERN, JOHN A..................................Hibbing, Minn.
REEDER, J. T.....................................Houghton, Mich.
REEDER, EDWIN C................1917 Fisher Bldg., Chicago, Ills.
REEDER, J. H.....................................Calumet, Mich.
REIGART, JOHN R..................................Nashwauk, Minn.
REYNOLDS, M. K.................430 E. Arch St., Marquette, Mich.
RICHARDS, WILLIAM J........................Crystal Falls, Mich.
RICHARDS, MORRIS EARL............................Virginia, Minn.
RICHARDS, WILLIAM J.............................Painesdale, Mich.
RICHEY, E. W...........211 Railway Exchange Bldg., Chicago, Ills.
RIDLEY, FREDERICK WILLIAM........................Calumet, Mich.
ROBERTS, HARRY....................................Duluth, Minn.
ROBERTS, RICHARD................................Negaunee, Mich.
ROBERTS, ALTON T...............................Marquette, Mich.
ROBERTSON, HUGH J...............................Escanaba, Mich.
ROBINSON, JAMES A.................................Hibbing, Minn.
ROHN, OSCAR.......................................Butte, Mont.
ROOD, DANA C......................................Hibbing, Minn.
ROSE, R. S.....................................Marquette, Mich.
ROSKILLY, JOSEPH.................................Virginia, Minn.
ROUGH, JAMES H..................................Negaunee, Mich.
ROWE, HENRY.....................................Ironwood, Mich.
ROWE, JAMES........................Osceola, Houghton Co., Mich.
RUEZ, GEORGE F.................................Ishpeming, Mich.
RUMSEY, SPENCER S.............610 Wolvin Bldg., Duluth, Minn.
RUNDLE, A. J...............................Iron Mountain, Mich.
RUSSELL, C. W.....................R. W. & F. Co., Detroit Mich.

SALOMONSON, H.....................................Norway, Mich.
SALSICH, L. R....................................Taconite, Minn.
SALVICK, WILLIAM V..............................Houghton, Mich.
SAVAGE, J. A......................................Hibbing, Minn.
SCADDEN, FRANK.............................Crystal Falls, Mich.
SCHLESENGER, H. J...............................Milwaukee, Wis.
SCHUBERT, GEORGE P...............................Hancock, Mich.
SCHULZE, W. J....................................Virginia, Minn.
SCOTT, D. D.....................535 W. Paul St., Rochester, N. Y.
SEAMAN, A. E....................................Houghton, Mich.
SEBENIUS, JOHN UNO................Wolvin Bldg., Duluth, Minn.
SEELYE, R. W..............................Sault Ste. Marie, Ont
SELLS, MAX.......................................Florence, Wis.
SENTER, A. W......................................Hubbell, Mich.
SEPARK, E. A......................Wolvin Bldg., Duluth, Minn.
SHEA, J. D......................................Bessemer, Mich.
SHELDON, A. F.............325 E. Hewitt Ave., Marquette, Mich.
SHERLOCK, THOMAS................................Escanaba, Mich.

SHERRERD, JOHN M..............................High Bridge, N. J.
SHIELDS, IRVIN J..............................Houghton, Mich.
SIEBENTHAL, W. A..............................Republic, Mich.
SILL, GEO. A....................504 Marquette Bldg., Chicago, Ills.
SIMMONS, CHARLES ....Beacon, Mich.
SJOGREN, PROF. H..........................Nynashamn, Sweden.
SKINNER, MORTIMER, B.558-560 W. Washington Bvld., Chicago, Ills.
SLAUGHTER, WILLIAM F..........................Vulcan, Mich.
SLINEY, DAVID J..............................Ishpeming, Mich.
SMITH, FRED ....Kearsarge, Mich.
SMITH, GEORGE M..............................Duluth, Minn.
SMITH, WILLIAM JOSEPH ....Mohawk, Mich.
SMITH, CARL G..............................Montreal, Wis.
SMITH, ALFRED L..............................Wakefield, Mich.
SMYTH, H. L......................Rotch Bldg., Cambridge, Mass.
SOADY, HARRY ....Duluth, Minn.
SORNBERGER, E. C..............208 Lancaster Ave., Buffalo, N. Y.
SPERR, F. W..............................Houghton, Mich.
SPORLEY, CHARLES L..........................Negaunee, Mich.
STACKHOUSE, POWELL ....Wallingford, Delaware Co., Pa.
STAKEL, CHARLES J..........................Ishpeming, Mich.
STATON, F. McM......................208 5th Ave., New York City.
STANTON, J. R....................11 William St., New York City.
STEPHEN, JAMES ....Ishpeming, Mich.
STEVENS, THOMAS J..........................Ironwood, Mich.
STEVENS, HORACE J..........................Houghton, Mich.
STOEK, H. H..................University of Illinois, Urbana, Ills.
STURTEVANT, H. B..............................Tuscon, Ariz.
SUESS, JOSEPH E..............................Negaunee, Mich.
SULLIVAN, F. J..............................Ironwood, Mich.
SUTHERLAND, D. E..............................Ironwood, Mich.
SWAIN, RICHARD A........General Electric Co., Minneapolis, Minn.
SWEENEY, E. F..............................Baxter Springs, Kan.
SWIFT, GEORGE D..............................Duluth, Minn.
SWIFT, H. LEIGH..............................Houghton, Mich.
SWIFT, PAUL D..............................Houghton, Mich.

TANCIG, A ....Hibbing, Minn.
TARR, S. W......................610 Wolvin Bldg., Duluth, Minn.
TAYLOR, JAMES HALL ....Box 485, Chicago, Ills.
THIEMAN, EDWARD ....Florence, Wis.
THOMAS, WILLIAM ....Ironwood, Mich.
THOMAS, KIRBY ....505 Pearl St., New York City.
THOMS, REUBEN KNIGHT..............................Ely, Minn.
THOMPSON, G. H..............................Hibbing, Minn.
THOMPSON, HENRY S..............................Beacon, Mich.
THOMPSON, A. W..............................Vulcan, Mich.

THOMPSON, JAMES R............................Ishpeming, Mich.
TILLINGHAST, EDWARD S........................Hibbing, Minn.
TOBIN, JAMES ....Florence, Wis.
TOWNSEND, C. V. R.............................Negaunee, Mich.
TRAVER, WILBER H....................Fisher Bldg., Chicago, Ills.
TREBILCOCK, JOHN ....Ishpeming, Mich.
TREBILCOCK, WILLIAM.....................North Freedom, Wis.
TREPANIER, HENRY ....Iron Mountain, Mich.
TREZONA, CHARLES ....Ely Minn.
TREVARROW, HENRY ....Negaunee, Mich.
TREVIRANUS, GEORGE ....Care D. M. & N. Docks, Duluth, Minn.
TRIPP, CHESTER D.........1515 Corn Exchange Bldg., Chicago, Ills.
TRUETTNER, IRVING W..........................Bessemer, Mich.
TUFTS, JOHN W.................................Milwaukee, Wis.
TURNER, CHAS. N..............Colby-Abbott Bldg., Milwaukee, Wis.
TYLER, CHARLES ....Negaunee, Mich.

UREN, WILLIAM J.................................Calumet, Mich.

VALLATT, BENJ. W..............................Ironwood, Mich.
VAN DYKE, W. D...............................Milwaukee, Wis.
VANDEVENTER, VIVIAN H.......................Ishpeming, Mich.
VAN EVERA, JOHN R...........................Marquette, Mich.
VAN EVERA, WILBUR............................Virginia, Minn.
VAN MATER, J. A....................55 Wall St., New York City.
VAN ORDEN, F. L.............................Houghton, Mich.
VAN VALKENBURG, ALLEN J..................Abbottsford, Wis.
VILAS, P. M..........425 New York Life Bldg., Minneapolis, Minn.
VIVIAN, JAMES G..................909 Alworth Bldg., Duluth, Minn.
VOGEL, F. A........................25 Broad St., New York City.

WADE, JEPTHA H....................Wade Bldg., Cleveland, Ohio.
WAGNER, JOHN M..............................Houghton, Mich.
WALL, JAMES S................................Iron River, Mich.
WALLACE, GEORGE ....Marquette, Mich.
WARE, JOHN FRANKLIN...............128 Park St., Dayton, Ohio.
WARE, FRED ....Negaunee, Mich.
WARREN, O. B.................................Hibbing, Minn.
WARRINER, S. D..............................Wilkesbarre, Pa.
WATSON, CHARLES H.......................Crystal Falls, Mich.
WEARNE, WILLIAM ....Hibbing, Minn.
WEBB, FRANCES J...............................Gilbert, Minn.
WEED, LOUIS B..............................Sunrise, Wyoming.
WELLS, PEARSON ....Ironwood, Mich.
WELKER, W. F...................................Ashland, Wis.
WENGLER, MATT P..........1055 Cambridge Ave., Milwaukee, Wis.
WESSINGER, W. E.................610 Wolvin Bldg., Duluth, Minn.

WESSINGER, HENRY J.............610 Wolvin Bldg., Duluth, Minn.
WEST, WILLIAM J..............................Hibbing, Minn.
WHITE, WILLIAM ....Virginia. Minn.
WHITE, EDWIN E..............................Ishpeming, Mich.
WHITEHEAD, R. G..............................Amasa, Mich.
WHITING, S. B..............................Swampscott, Mass.
WHITESIDE, DR. JOHN W..............................Ironwood, Mich.
WILLEY, NORMAN W..............................Hibbing, Minn.
WILKINS, WILLIAM ....Ashland, Wis.
WILLIAMS, JAMES H..............................Ishpeming, Mich.
WILLIAMS, THOMAS H..............................Ely, Minn.
WILLIAMS, HERBERT H..............................Marquette, Mich.
WILLIAMS, PERCIVAL S..............................Ramsay, Mich.
WILSON, EUGENE B..............................Scranton, Pa.
WINCHELL, HORACE V........505 Palace Bldg., Minneapolis, Minn.
WINTER, JOSEPH H..............................Negaunee, Mich.
WITHERBEE, F. S..............................Port Henry, New York.
WOODBRIDGE, DWIGHT E..............................Duluth, Minn.
WOODWORTH, G. L..............................Iron River, Mich.
WOODWORTH, R. B..............427 Carnegie Bldg., Pittsburgh, Pa.

YOUNG, H. OLIN..............................Ishpeming, Mich.
YOUNGS, FRANK W..............................Iron River, Mich.
YOUNGS, GEORGE C..............................Florence, Wis.
YOUNGS, G. W..............................Iron River, Mich.
YUNGBLUTH, A. J..............................Ishpeming, Mich.

DECEASED MEMBERS.

ARMSTRONG, J. F....................................March 3rd, 1898
BAWDEN, JOHN T..1899
BENNETT, JAMES H..
BROOKS, T. B..1902
BULLOCK, M. C...........................January 12th, 1899
COWLING, NICHOLAS 1910
CONRO, ALBERT ....January 10th, 1901
CLEAVES, WILL S..1910
DANIELS, JOHN ....September 13th, 1898
DICKENSON, W. E..................................June 15th, 1899
DOWNING, W. H......................................October, 1906
DUNCAN, JOHN ....June, 1904
DUNSTON, THOMAS B..
GARBERSON, WILLIAM R..........................April 29th, 1908
HALL, CHAS. H.....................................February, 1910
HARPER, GEORGE VANCE..............................March, 1905
HAYDEN, GEORGE ....July 27th, 1902
HINTON, FRANCIS 1896
HOLLAND, JAMES ....September 3rd, 1900
HOLLEY, S. H..July 4th, 1899
HOUGHTON, JACOB ....December 30th, 1903
HYDE, WELCOME ....
JEFFERY, WALTER M..............................May 26th, 1906
JOCHIM, JOHN W.............................January 17th, 1905
KRUSE, JOHN C...............................October 28th, 1907
LUSTFIELD, A ....May 26th, 1904
LYON, JOHN B...............................February 13th, 1900
MARR, GEORGE A....................................March, 1905
MITCHELL, SAMUEL ....May 10th, 1908
M'VICHIE, D ....September 14th, 1906
NINESE, EDMUND ....January 3rd, 1909
OLIVER, HENRY W............................February 8th, 1904
PEARCE, H. A...1905
PERSONS, GEORGE R..........................March 26th, 1908
ROBERTS, E. S..
RYAN, EDWARD.. 1901
SHEPHARD, AMOS ....June 6th, 1905
STANLAKE, JAMES ....September 23rd, 1910
STANTON, JOHN ....February 23rd, 1906
THOMAS, HENRY ....December, 1905
TREVARTHEN, G. C.................................January, 1898
VAN DYKE, JOHN H...1906
WALLACE, JOHN 1898
WHITE, PETER ....June 6th, 1908
WHITNEY, J. D...1894
WILLIAMS, W. H...1897

LIST OF PAPERS PUBLISHED IN PRECEDING VOLUMES.

1901.

1902.

1903.

1904.

1905.

DISCUSSIONS.

1906.

1908.

1909.

LIST OF MEETINGS OF THE INSTITUTE AND THEIR LOCALITIES FROM ITS ORGANIZATION TO AUGUST, 1910.

No.	Place.	Date.	Proceedings.
1	Iron Mountain, Mich	March 22-23, 1893	Vol. I
2	Houghton, Mich	March 7-9, 1894	Vol. II
3	Mesabi and Vermilion Ranges	March 6-8, 1895	Vol. III
4	Ishpeming, Mich	August 18-20, 1896	Vol. IV
5	Ironwood, Mich	August 16-28, 1898	Vol. V
6	Iron Mountain, Mich	February 6-8, 1900	Vol. VI
7	Houghton, Mich	March 5-9, 1901	Vol. VII
8	Mesabi and Vermilion Ranges	August 19-21, 1902	Vol. VIII
9	Ishpeming, Mich	August 18-20, 1903	Vol. IX
10	Ironwood, Mich	August 16-18, 1904	Vol. X
11	Iron Mountain, Mich	October 17-19, 1905	Vol. XI
12	Houghton, Mich	August 8-10, 1906	Vol. XII
13	Mesabi and Vermilion Ranges	June 24-27, 1908	Vol. XIII
14	Ishpeming, Mich	August 25-27, 1909	Vol. XIV
15	Ironwood, Mich	August 24-26, 1910	Vol. XV

Note—No meetings were held in 1897, 1899 and 1907.

RULES OF THE INSTITUTE.

I.

OBJECTS.

The objects of the Lake Superior Mining Institute are to promote the arts and sciences connected with the economical production of the useful minerals and metals in the Lake Superior region, and the welfare of those employed in these industries, by means of meetings of social intercourse, by excursions, and by the reading and discussion of practical and professional papers, and to circulate, by means of publications among its members the information thus obtained.

II.

MEMBERSHIP.

Any person interested in the objects of the Institute is eligible for membership.

Honorary members not exceeding ten in number, may be admitted to all the privileges of regular members except to vote. They must be persons eminent in mining or sciences relating thereto.

III.

ELECTION OF MEMBERS.

Each person desirous of becoming a member shall be proposed by at least three members approved by the Council, and elected by ballot at a regular meeting (or by ballot at any time conducted through the mail, as the Council may prescribe), upon receiving three-fourths of the votes cast. Application must be accompanied by fee and dues as provided by Section V.

Each person proposed as an honorary member shall be recommended by at least ten members, approved by the Council, and elected by ballot at a regular meeting, (or by ballot at any time conducted through the mail, as the Council may prescribe), on receiving nine-tenths of the votes cast.

IV.

WITHDRAWAL FROM MEMBERSHIP.

Upon the recommendation of the Council, any member may be stricken from the list and denied the privilege of membership, by the vote of three-fourths of the members present at any regular meeting, due notice having been mailed in writing by the Secretary to him.

V.

DUES.

The membership fee shall be five dollars and the annual dues five dollars, and applications for membership must be accompanied by a remittance of ten dollars; five dollars for such membership fee and five dollars for dues for the first year. Honorary members shall not be liable to dues. Any member not in arrears may become a life member by the payment of fifty dollars at one time, and shall not be liable thereafter to annual dues. Any member in arrears may, at the discretion of the Council, be deprived of the receipt of publications or be stricken from the list of members when in arrears six months; Provided, That he may be restored to membership by the Council on the payment of all arrears, or by re-election after an interval of three years.

VI.

OFFICERS.

There shall be a President, five Vice Presidents, five Managers, a Secretary and a Treasurer, and these Officers shall constitute the Council.

VII.

TERM OF OFFICE.

The President, Secretary and Treasurer shall be elected for one year, and the Vice Presidents and Managers for two years, except that at the first election two Vice Presidents and three Managers shall be elected for only one year. No President, Vice President, or Manager shall be eligible for immediate re-election to the same office at the expiration of the term for which he was elected. The term of office shall continue until the adjournment of the meeting at which their successors are elected.

Vacancies in the Council, whether by death, resignation, or the failure for one year to attend the Council meetings, or to perform the duties of the office, shall be filled by the appointment of the Council, and any person so appointed shall hold office for the remainder of the term for which his predecessor was elected or appointed; Provided, That such appointment shall not render him ineligible at the next election.

VII.

DUTIES OF OFFICERS.

All the affairs of the Institute shall be managed by the Council except the selection of the place of holding regular meetings.

The duties of all Officers shall be such as usually pertain to their offices, or may be delegated to them by the Council.

The Council may in its discretion require bonds to be given by the Treasurer, and may allow the Secretary such compensation for his services as they deem proper.

At each annual meeting the Council shall make a report of proceedings to the Institute, together with a financial statement.

Five members of the Council shall constitute a quorum; but the Council may appoint an executive committee, business may be transacted at a regularly called meeting of the Council, at which less than a quorum is present, subject to the approval of a majority of the Council, subsequently given in writing to the Secretary and recorded by him with the minutes.

There shall be a meeting of the Council at every regular meeting of the Institute and at such other times as they determine.

IX.

ELECTION OF OFFICERS.

Any five members not in arrears, may nominate and present to the Secretary over their signatures, at least thirty days before the annual meeting, the names of such candidates as they may select for offices falling under the rules. The Council, or a committee thereof duly authorized for the purpose, may also make similar nominations. The assent of the nominees shall have been secured in all cases.

No less than two weeks prior to the annual meeting, the Secretary shall mail to all members not in arrears a list of all nominations made and the number of officers to be voted for in the form of a letter ballot. Each member may vote either by striking from or adding to the names upon the list, leaving names not exceeding in number the officers to be elected, or by preparing a new list, signing the ballot with his name, and either mailing it to the Secretary, or presenting it in person at the annual meeting.

In case nominations are not made thirty days prior to the date of the annual meeting for all the offices becoming vacant under the rules, nominations for such offices may be made at the said meeting by five members, not in arrears, and an election held by a written or printed ballot.

The ballots in either case shall be received and examined by three tellers appointed at the annual meeting by the presiding officer; and the persons who shall have received the greatest number of votes for the several offices shall be declared elected. The ballot shall be destroyed, and a list of the elected officers, certified by the tellers, shall be preserved by the Secretary.

X.

MEETINGS.

The annual meeting of the Institute shall be held at such time as may be designated by the Council. The Institute may at a regular meeting select the place for holding the next regular meeting. If no place is selected by the Institute it shall be done by the Council.

Special meetings may be called whenever the Council may see fit; and the Secretary shall call a special meeting at the written request of twenty or more members. No other business shall be transacted at a special meeting than that for which it was called.

Notices of all meetings shall be mailed to all members at least thirty days in advance, with a statement of the business to be transacted, papers to be read, topics for discussion and excursions proposed.

No vote shall be taken at any meeting on any question not pertaining to the business of conducting the Institute.

Every question that shall properly come before any meeting of the Institute, shall be decided, unless otherwise provided for in these rules, by the votes of a majority of the members then present.

Any member may introduce a stranger to any regular meeting; but the latter shall not take part in the proceedings without the consent of the meeting.

XI.

PAPERS AND PUBLICATIONS.

Any member may read a paper at any regular meeting of the Institute, provided the same shall have been submitted to and approved by the Council, or a committee duly authorized by it for that purpose prior to such meeting. All papers shall become the property of the Institute on their acceptance, and with the discussion thereon, shall subsequently be published for distribution. The number, form and distribution of all publications shall be under the control of the Council.

The Institute is not, as a body, responsible for the statements of facts or opinion advanced in papers or discussions at its meetings, and it is understood, that papers and discussions should not include personalities, or matters relating to politics, or purely to trade.

XII.

AMENDMENTS.

These rules may be amended by a two-thirds vote taken by letter ballot in the same manner as is provided for the election of officers by letter ballot; Provided, That written notice of the proposed amendment shall have been given at a previous meeting.

THE FIFTEENTH ANNUAL MEETING, AUGUST 24th, 25th, 26th, 1910.

LOCAL COMMITTEES.

General Arrangement Committee.

John M. Bush, Chairman.
George H. Abeel, Henry Rowe, Luther C. Brewer, Grant S. Barber, D. E. Sutherland.

Finance Committee.

Luther C. Brewer, Chairman.
L. M. Hardenburgh, Will A. Cole, C. E. Walton, F. H. Kearney.

Transportation Committee.

George H. Abeel, Chairman.
G. J. Quigley, O. W. Johnstone, A. J. VanValkenburg, W. F. Welker.

Entertainment Committee.

D. E. Sutherland, Chairman.
F. J. Sullivan, B. W. Shove, B. E. Jussen, F. J. Alexander.

Reception Committee.

Henry Rowe, Chairman; Judge S. S. Cooper, S. S. Curry, J. H. Goudie, C. E. Bennett, J. S. Kennedy, James Devoy, B. W. Vallat, Fred Fehr, P. S. Williams, E. D. Nelson, G. L. Olson, Robt. A. Douglas, S. J. Perkins, Wm. Bond, T. J. Stevens, S. J. Gribble, A. G. Hedin, Thos. J. McNamara, James Stanlake, Frank Blackwell, Kimball Clark, P. H. Cummings, Geo. A. Curry, Carl E. Erickson, Oscar E. Olson, I. W. Truettner, Robert King, Michael Lambrix, J. D. Shea, Pearson Wells, William Wilkins, C. E. Houk, C. M. Humphrey, Belmont Waples, Joseph Davis, E. G. Brady, J. A. Tederstrom, W. H. Moore, J. W. Mullen, J. H. Cannon, Arthur Redner, John V. Brennan, J. S. Monroe, W. H. Madison, F. H. Lesselyong, Dr. A. H. Thomas, Dr. E. H. Kelly, Dr. J. W. Whiteside, Dr. Pierpont Wm. Tolan, C. G. Rogers.

Committee on Arrangements and Reception for Chicago and Gary.

E. D. Brigham, Chairman; Oliver J. Abeel, Frederick W. Adgate, R. H. Aishton, J. W. Amberg, William A. Amberg, C. Kemble Baldwin, E. D. Brigham, E. D. Brigham, Jr., John Jacob Brown, George R. Carr, Raymond B. Carter, H. C. Cheyney, Horace S. Clark, F. G. Coggin, A. B. Conover, Frank Drake, W. A. Gardner, B. W. Goodsell, Elbert E. Hickok, J. Winchester Holman, Herman H. Hopkins, Jr., Roy D. Hunter, August R. Jettner, N. F. Leopold, F. B. Macomber, John Mills, William A. Mitchell, S. T. Nelson, Edwin C. Reeder, E. W. Richey, Mortimer B. Skinner, H. H. Stoek, Wilber H. Traver, Chester D. Tripp.

ITINERARY.

Wednesday, August Twenty-Fourth.

Headquarters of the Institute will be located in the Ironwood Club Rooms on the second floor of the building at the corner of Suffolk and Aurora streets.

During the meeting the privilege of the following clubs is extended to members and guests during their stay in the city.

Alpha Omega Club, 121 Suffolk street.

Ironwood Club, Corner Suffolk and Aurora streets.

10:00 a. m. Special train will leave the C. & N. W. depot for a trip through the mines in the City of Ironwood, returning to town at 12 o'clock, noon.

2:30 p. m. Special train will leave C. & N. W. depot for a trip through the mines of Bessemer and Wakefield, returning to Ironwood at 6:00 o'clock, p. m.

8:00 p. m. Business session at Pierce Theater, Corner Suffolk street and McLeod avenue.

11:00 p. m. (Sharp). Leave by special train via C. & N. W. R'y., for Chicago and Gary. Sleeping cars will be ready for occupancy at the close of the business meeting.

On account of the laws regulating railway transportation, whereby trains cannot be chartered for occasions of this kind, all those participating in the trip to Gary and Chicago are obliged to pay fare.

Tickets may be secured at Institute Headquarters in the Ironwood Club rooms.

For meals to be served in the dining cars, a special rate of $1.00 per meal has been made.

No charge will be made for sleeping car accommodations. Reservations will be made at Institute Headquarters.

Thursday, August Twenty-Fifth.

6:00 a. m. Leave Appleton Junction, Wis. The route from here to Milwaukee is through the cities of Neenah, Menasha, Oshkosh, Fond du Lac and West Bend. Breakfast will be served in the dining cars, which will be run through to Chicago.

9:00 a. m. Leave Milwaukee via the Shore Line of the Chicago & Northwestern Railway, en route to Chicago, passing the Bay View Works of the Illinois Steel company (Steel Corporation) and through the prominent manufacturing cities of Cudahy, South Milwaukee, where a thirty minute stop will be made as the guests of the Bucyrus Steam Shovel & Dredge Co., whose plant is here; Racine, Kenosha, Waukegan, the location of the American Steel & Wire plant of the Steel corporation; and North Chicago. Close to the last named point the U. S. Naval Training Station will be seen, occupying 170 acres of land extending from the Northwestern Line to the Lake Shore. A harbor has been dredged, and forty buildings have been erected. Millions of dollars are being expended to make this institution one of the best and most complete of its kind for a seaman's training, and accommodations will be provided for 250 men.

At Lake Bluff station a detour from the Shore Line will be made to reach the Northwestern's other double track line between Chicago and Milwaukee, and over this line the train will proceed to Mayfair.

11:00 a. m. Arriving at Mayfair and from here to the C. & N. W. R'y. Chicago Shops over the "Cut Off" between the Wisconsin Division and the Omaha Division. Before reaching the Chicago Shops the 40th street freight station is passed, being located on the left as we go on. This station is the point of transfer of carload freight interchanged with other railroads. This freight yard has a capacity of 5,000 cars and an average of 7,000 cars per day are handled through it. The yard is divided into six sections. The Chicago Shops of the C. & N. W. R'y are among the largest of the kind in this vicinity. They occupy a tract of 240 acres and about 3,200 men are employed here. Notwithstanding the capacity of these shops, only repair work on rolling stock is done, all new equipment being purchased.

11:30 a. m. Leave the Chicago Shops and here the train passes onto the Omaha Division, forming the double track road between Chicago and the Missouri River. This division is covered for about a mile and a half eastward to the branch extending south to the other freight yards of the plant of the Sullivan Machinery Company, manufacturers of mining machinery, and well known to the members of this party.

11:45 a. m. After a visit at the Sullivan Machinery plant, automobiles will be taken through the courtesy of the Sullivan Machinery Co., for a trip over the West Park Boulevards, through Garfield and Douglas Parks, to the Ryerson Plant.

1:30 p. m. Arrive at the J. T. Ryerson & Son Plant, who will be the hosts at luncheon, followed by an inspection of this industry.

3:00 p. m. Automobiles will be taken to the National League Ball Park, where the world's champion baseball team, the "Cubs," will be seen in contest with the New York "Giants."

5:00 p. m. Or at the close of the game, automobiles will be taken for the ride to the train, which will be ready at the Northwestern's yard near Ashland Avenue and 15th street. From this yard, the Northwestern Line continues to its connection with the Lake Shore & Michigan Southern Railway at Clark and 16th streets, where the train will be switched to the tracks of that company.

5:30 p. m. Leave via the L. S. & M. S. R'y. for Gary, 25 miles from Chicago, passing through the southern portions of Chicago and Englewood, South Chicago, where are the South Works of the Illinois Steel Company (Steel Corporation), Whiting, the refining and distributing plant of the Standard Oil Co., and Buffington, where the Universal Portland Cement Co. (Steel Corporation) plant is located.

6:30 p. m. Arrive at Gary. This wonderful new city was started in April, 1906, by the United States Steel corporation, and is fast becoming the Pittsburg of the West. A complete description of this interesting place will be found in another form.

8:30 p. m. Second business session in Assembly Hall, Sixth Avenue and Broadway. Special trains will be parked at Virginia street, L. S. & M. S. R'y., one block east of station.

Friday, August Twenty-Sixth.

9:30 a. m. Assemble at the main entrance of the Indiana Steel Company, Gary Works, for an inspection trip through the plant by the courtesy of E. J. Buffington, President; F. T. Bentley, Traffic Manager; Geo. G. Thorpe, Vice President.

1:00 p. m. Leave Gary via the L. S. & M. S. R'y. for Chicago.

2:30 p. m. Arrive at the La Salle Street Station, Chicago. Cars will then be switched to the Wells Street station of the C. & N. W. R'y. and to Park Row station of the Soo Line, according to arrangements.

6:30 p. m. Banquet in the Gold Room at the Congress Hotel Annex (Second Floor.)

12:00 Midnight. Leave Wells Street Station via C. & N. W. R'y. for the Marquette and Menominee Iron Ranges and leave Park Row station of the Soo Line at the same time for the Gogebic, Mesaba and Vermilion Ranges.

Saturday, August Twenty-Seventh.

2:30 p. m. Arrive at Iron Mountain via C. & N. W. R'y.

4:20 p. m. Arrive at Ishpeming via C. & N. W. R'y.

2:30 p. m. Arrive at Ironwood via Soo Line.

LOCAL MINE OFFICERS AND OPERATORS.

Anvil, Newport and Palms.

L. C. Brewer, Manager; B. W. Vallat, Superintendent; Newport Mining Co., operators.

Ashland.

John M. Bush, Superintendent; Cleveland-Cliffs Iron Co., operators.

Atlantic, Aurora, East Norrie, Norrie, Pabst and Tilden.

D. E. Sutherland, Superintendent; Henry Rowe, Assistant Superintendent; Oliver Iron Mining Co., operators.

Brotherton, Mikado, Pike and Sunday Lake.

C. E. Walton, General Superintendent; W. J. Davis, Assistant; Pickands, Mather & Co., operators.

Colby and Ironton.

G. S. Barber, Superintendent; Corrigan, McKinney & Co., operators.

Carey.

L. M. Hardenburgh, Superintendent; Pickands, Mather & Co., operators.

Germania.

Robert King, Superintendent; Harmony Iron Co., operators.

Montreal, Ottawa, Eureka and Castile.

Geo. H. Abeel, General Manager; P. S. Williams, Frank B. Goodman, Assistants; Ogelbay, Norton & Co., operators.

Yale.

W. E. McRandall, Superintendent; Ashland Iron & Steel Co., operators.

Pence and Hennepin.

J. S. Kennedy, Superintendent; Jones & Laughlin Steel Co., operators.

THE GOGEBIC RANGE.

DESCRIPTIVE.

The iron bearing formation of the Gogebic Iron Range extends almost unbroken from Lake Gogebic, in Michigan, on the east to Mineral Lake in Wisconsin on the west.

The iron formation is found both east and west of these limits, having a total length of about 80 miles, but is not traced continuously for the entire distance. The productive portion of the formation extends from the Castile mine located one and one half miles east of the village of Wakefield in Michigan, to the Atlantic mine in Wisconsin a distance of about 20 miles. The general trend of the formation is north of east with a dip universally to the north varying from 55 to 75 degrees. The formation varies in the width from 300 feet to 3 miles in the widest portion.

The formations are for the most part regular. They rest on the granite to the south and are overlaid by trap of the Keweenaw series on the north. The iron bearing series is divided into four members. The lowest, a cherty limestone, thin and not generally present except on the western end. Second, quartz-slate, slatey in the lower portions but becoming hard and massive in the upper portions. Third, the ore bearing member consisting of ferruginous cherts, schists and ore bodies. The fourth is composed of ferruginous slates, grey wackes and schists. The ore is deposited in general up on the quartizite foot wall the largest deposits being in troughs formed between the quartizite foot wall and diorite dikes that cut across the ore formation at right angles to the foot wall.

The relation of the various formations, and that of the ore to the dikes is shown on the cross section, accompanying the map. The diorite dikes which are numerous in the Ironwood district are to a great extent missing east of the Black river, in Michigan, and west of the Montreal river in Wisconsin. East of the Black river, and in the vicinity of Wakefield the formation is more broken, the mines are north of the regular foot wall and the ore is found in the extreme north limit of the iron formation, within two or three hundred feet of the trap of the copper range with the upper member of the series missing. The universal practice in the development of the range was to sink the shafts on the foot wall in the ore. As the ore was removed in the process of mining these shafts all caved more or less and were difficult to maintain. They are now being abandoned and replaced by others one hundred and fifty to two hundred feet back in the foot wall.

The ores of the Gogebic range are mostly soft red hematite with lesser varying amount of hard steel blue hematite. The iron contents vary from 53 to 63 per cent iron, averaging about 61 per cent, phosphorus varies from .027 to .157 averaging about .045. The moisture varies 8 to 15 per cent averaging about 10 per cent. Manganese is present in the ore of a few mines varying from 1 to 9 per cent.

ASHLAND MINE.

The Ashland is the most westerly of the mines in Michigan. It was one of the first properties opened on the range by the Ashland Mining Company, shipping 6,471 tons in 1885. It was operated under various managements until May 1901 when it was leased by the Hayes Mining Company to the Cleveland-Cliffs Iron Company. This Company sunk a new foot wall shaft, No. 9, and remodeled and rebuilt the entire surface plant and equipment. Two shafts are operated, No. 3, 850 feet deep, sunk on the vein; No. 9, 12 by 18 feet, 1690 feet deep. This is the principal shaft located about 700 feet from the east property line and 150 feet south of the ore body. The boiler plant consists of two Sterling water tube boilers and four 72 inch by 18 feet horizontal return tubular boilers. The mechanical equipment consists of a Webster, Camp and Lane, 26 by 48 geared hoist with five drums, 10 feet in diameter by 5 feet 7 inch face, and an Ingersoll-Seargent duplex air compressor, 18 by 42 steam and 18 by 42 air. The change house is a brick structure with metal lockers and complete modern equipment. Total shipments 5,386,-884 tons.

NORRIE MINE.

The Norrie is located next east to the Ashland. This is the most widely known mine on the range. It was opened by the Metropolitan Land & Iron Company in 1885, shipping the first season 15,419 tons. It continued under their management until 1897 when it was taken over by the Oliver Iron Mining Company and now forms one of the group known as the Norrie group operated by this company. It is operated by two shafts, "A" and "B" sunk in the foot 150 to 200 feet south of the ore body. "A" shaft is 1,990 feet deep and was the first shaft on the range to be lined with steel sets. "B" shaft is 1,790 feet deep and also steel lined. The boiler house containing four 72 inch by 18 feet horizontal return tubular boilers, is built according to the plans adopted by this Company as a standard for boiler houses, and is provided with a tile stack 125 feet high and 72 inches internal diameter. This boiler house like the other standard boiler houses is equipped with a Webster feed water heater and coal elevator. Engine house "A" contains a 30 by 72 Reynolds first motion Corliss hoisting engine, connected to one drum, 12 feet in diameter, with a 9 foot face, operating the skips in "A" shaft. Engine house "A" and "B" contain a 20 by 42 M. C. Bullock, simple reversible link motion, Corliss hoisting engine geared to two drums, 10 feet in diameter, 65 inch face, operating the cage and counterbalance in "A" shaft, also a 20 by 42 Reynolds first motion Corliss hoisting engine, operating two 4 ton skips in balance in "B" shaft.

EAST NORRIE

Is a continuation of the Norrie ore body to the east and is one of the Norrie group of the Oliver Iron Mining Company. Two shafts are in operation, "C" a vertical hanging shaft, 1,190 feet deep and "D" a foot wall shaft 1,290 feet deep. The mechanical equipment at "D" shaft comprises two 24 by 48 M. C. Bullock geared hoists with drums 10 feet in diameter and a 7 foot face. One operating two 5 ton skips, the other the cage. The boiler house contains four 72 inch by 18 feet horizontal return tubular boilers. At "C" shaft the boiler plant is two 250 H. P. Cahall water tube boilers. The engine house contains a duplex 24 by 48 Bullock engine connected to two drums, 8 feet in diameter, with a 9 foot face, one drum operating two 6 ton skips in balance and the other two single deck cages. The machine shop, blacksmith shop, carpenter shop, laboratory and warehouse are located here.

AURORA

Joins the East Norrie on the east, and is included in the Norrie group of the Oliver Iron Mining Company. Was opened in 1886 by the Penokee & Gogebic Development Company and continued under their management until 1899 when it was taken over by the Oliver Iron Mining Company. It is operated by three shafts, two active, and the third is now being sunk. No. 1 is a foot wall shaft 1,230 feet deep, "A" is a hanging wall vertical shaft 1,020 feet deep. The steel shaft house here was the first erected on the range. "F" 1,240 feet deep is a foot wall shaft now being sunk. At "A" shaft the boiler plant contains two 250 H. P. Cahall water tube boilers, one 250 H. P. Sterling water tube boiler. The 22 & 40x42 steam, 24 & 38x42 air, Ingersoll-Rand air compressor is located here. The engine house contains a 20x42 Webster, Camp & Lane duplex hoisting engine connected to one 7 foot diameter by 9 foot face drum, operating in balance two single deck cages with three ton skips attached. No. 1 shaft engine house contains a 24x48 simple link motion, hoisting engine, geared to one drum, 10 feet in diameter with 66 inch face, operating two 4 ton skips, and, the electric plant, a 200 K. W. direct current, 250 volt, belt driven generator. At "F" shaft is a new steel head frame, and a new engine house 50x80 feet. This engine house will contain two hoisting engines, one for the cage and the other for the skips. The skip engine, a 28x60 Allis Chalmers duplex first motion, connected to a 12 foot diameter drum, is now installed.

PABST.

The Pabst lies next east of the Aurora on the trend of the formation. This is one of the Norrie group of the Oliver Iron Mining Co. It is operated by two shafts, "C," an old vertical hanging wall shaft 1,560 feet deep, and "G," a new foot wall shaft 1,650 feet deep. "C" boiler house contains two 72x18 feet horizontal return tubular boilers, the engine house a 24x48 Sullivan link motion hoist geared to one drum 10 foot diameter, with 8 foot face, operating two 5 ton skips in balance.

At "G" shaft is a new standard boiler house 50x120 feet, equipped with six 72x18 feet boilers, with a 150 foot tile chimney, having internal diameter of 108 inches.

The coal trestle has a steel deck. This boiler house furnishes steam for new "F" and the No. 1 Aurora hoists, and electrical plant as well as the new "G" Pabst engine house. The "G" engine house is 50x210 feet. Both this and the boiler house are fire proof structures, with metal frames brick lined and metal sheathed. The engine house is equipped with a 20 ton traveling crane. There is installed a 28x60 Allis-Chalmers duplex first motion hoist, connected to a 12 foot drum with 12 foot face to operate two 5 ton skips in balance in "G" shaft, and a 26 & 52x48 steam, 28 & 45x48 air, Nordberg cross compound air compressor. There is yet to be installed an electric generating plant and cage hoist.

NEWPORT.

The Newport lies east of the Pabst and includes the

Newport and Bonnie. It was opened in 1886 under the name of the Iron King. It is operated by the Newport Mining Company. The Newport is the deepest mine on the range, having opened up a large body of ore at a depth of 2,000 feet, through the persistent efforts of Mr. J. R. Thompson, former manager of the property. This pioneer deep exploring of the Newport has proven the ore to exist in depth on the Gogebic Range. It is operated through two shafts, "D," a foot wall shaft 2,360 feet deep, and "K," 2,300 feet deep. The exploring shaft was sunk nearly 1,000 feet through barren ground and finally reached the ore at a depth of approximately 2,000 feet.

EQUIPMENT "D" SHAFT—NEWPORT MINE.

In this paper it is the writer's intention to describe briefly the equipment of the Newport Mine, particular attention being given to that which applies to the operation of "D" Shaft. This, I believe, will be of interest to members of the Institute for the reason that this shaft is probably one of the largest producers of any single underground operation of it's depth in the Lake Superior region.

Water for miscellaneous use is pumped through a 6 inch main from a central steam operated station, located in a valley at the east end of the property, to a 16x30 foot tank located on top of the hill, south of the General Office. From this tank it is distributed to the various mine buildings and fire hydrants.

To furnish clean water for domestic purposes at the mine location, general office, laboratory, and other places where such water is necessary, an 8x3¼x12 Prescott Duplex Pot Form pump is located on the 7th level of "K" shaft.

All water for boiler feed purposes, after passing through the air cylinder jackets and inter-cooler of the air compressor, flows to a 2,000 H. P. Marion Feed Water Heater, where it is heated to as high a temperature as possible with exhaust steam from the two hoisting plants, located in this station, the supply to the heater being controlled by an automatic regulating valve. From the heater the water flows to an auxiliary heater located in the boiler house. In this heater exhaust steam from the feed pump makes up the small loss in heat due to the transfer.

The feed pump equipment consists of two 16x10x16 Burnham Plunger Pumps, manufactured by the Union Steam Pump Works, one of these pumps being held in reserve at all times. Steam and water piping are arranged, with necessary valves, so that in cases of emergency the reserve pump can be placed in operation with the least possible delay. Both pumps discharge into a 5 inch extra heavy header from which it is distributed by suitable valves and piping to the different boilers. This distribution at present is hand operated, but we are now considering the installation of an automatic control for this purpose.

The boiler installation consists of one 400 H. P. and five 250 H. P. Wickes Vertical Water Tube Boilers, a total of 1,650 H. P., all equipped with Rooney Automatic Stokers, manufactured by the Westinghouse Machine Company.

All coal for the plant is delivered by suitable belt conveyors and an elevator to bunkers located above the boilers. From here it is fed through hand operated gates to the stoker hoppers. Ashes are removed in a small car which operates in a tunnel under the boiler house floor. All coal and ash handling equipment is electrically operated.

The steam piping consists of a 16 inch header located back of the boilers, arranged with necessary fittings to receive the leads from the different boilers, and outlets for three main steam lines, two of which, an 8 inch and a 12 inch, extend in an underground ditch to the main power house, the third, a 6 inch, to the shaft for underground pumping; 150 pounds working pressure is used for all purposes.

The hoisting equipment at this shaft consists of two Thompson-Greer hoists of rather unusual design, in that the drums are set tandem to each other, connections to the outside drum being made through two parallel rods on the crank discs. Each hoist is operated by two 24x48 Corliss engines, the drums being 8 feet in diameter by 12 foot face, and grooved for 1¼ inch rope. As each drum is equipped with an independent friction and brake the plants are extremely flexible, especially where hoisting from different levels, as it allows the balancing of skips from any point desired very quickly. The No. 1, or west hoist is used exclusively for handling ore and rock; the east hoist being used exclusively for men, supplies, etc. By substituting skips for cages on the latter, ore or rock can be hoisted with same if necessary. The Richmond signal system is being used.

Compressed air for use on surface and underground is furnished by a 16x32—17½ & 29x42 Cross Compound two stage Nordberg Air Compressor of 2,500 cubic feet capacity.

Electrical equipment consists of a 10x20x36 Tandem Compound Nordberg engine, direct connected to a 150 K. W. 250 Volt D. C. Westinghouse generator, and a 14x28x36 Cross Compound Allis-Chalmers engine, direct connected to a 250 K. W. 250 Volt D. C. generator. The switch board, built by Westinghouse Electric & Manufacturing Company, consists of two generator and two feeder panels complete with necessary instruments and control switches.

Future electrical installations include a 500 K. W. Mixed Pressure Turbine being built by the General Electric Company, with the necessary regenerator, condensing apparatus, etc.

All underground water from the entire mine is now being pumped through "D" shaft with two 11½x18x30x7x24 Triple Expansion and Condensing Pumps of the Prescott Pot Form type. These pumps are located on the 19th and 10th levels, each having a vertical head of about 1,100 feet. A 22x42x4¾x36 Prescott Cross Compound Corliss pumping engine is now being installed on the 19th level which will pump from this level to surface in one lift. For the extreme pressure due to this head, amounting to approximately 1,100 pounds at the pump, special design in both the pump and discharge column was necessary. With this installation completed the two stage operation with "Triples" will serve as an emergency system.

"D" shaft is 28 feet 8 inch x 6 feet and divided into five compartments, four of which are used for skip and cage roads, the fifth for ladders, pipes, power lines, etc. The surface equipment includes a steel shaft house built by The Worden-Allen Company, of Milwaukee, and an electrically operated traveling crane for handling material, skips, etc. The shaft is lined with steel throughout, being lagged with peeled cedar lagging. Forty pound rail is used for all skip roads, with 6x8 tamarack for back runners. All underground operating stations are equipped with necessary pockets into which material is dumped from side dump steel tram cars.

All underground tramming to the shaft is handled with 9,000 pound Westinghouse Single End Control Electric locomotives. These machines are equipped with two 10 H. P. motors, which are connected through suitable gearing to each axle. Thirty pound rail is used on all haulage tracks.

Surface buildings of recent construction include a General Office building, captains' and timekeepers' office, dry, power house, machine shop, and boiler house. Hand operated traveling cranes are installed in the machine shop and power house for the handling of heavy machinery. Shops are equipped with the miscellaneous tools found necessary for the general manufacturing and repair work of a mining operation. Wherever possible, these tools are operated electrically.

The main dry building is equipped with steel lockers, enameled cast iron lavatories and shower baths. A total of 768 men can be accommodated, each party of two being furnished two lockers, one of which is used for street and the other for underground clothes. Equipment includes necessary piping for heating, also hot and cold water for washing. Hot water for washing is taken from the feed water heater at the power house. Mine buildings are heated from central hot water heating station located in the basement of the power house. The water for the system is heated in closed heaters by exhaust steam from the hoists, being circulated by a 10 H. P. DeLaval Steam Turbine Centrifugal pump.

A complete central energy telephone system has been installed during the present summer, connection now being possible through a switch board, located in the General Office, between all mine buildings, shafts and underground stations. Two trunk lines from the city offices of the telephone company make the entire system available for local, city and long distance service when necessary.

DAVIS.

The Davis joins the Newport on the east and is operated by the Oliver Iron Mining Company. A new foot wall shaft is being sunk. The present depth is 1,250 feet. This shaft, like all new shafts of this company, is lined with steel and provided with a steel head frame. There is a standard boiler house 50x60 feet, containing five 72x18 feet horizontal return tubular boilers and provided with a 125 foot tile chimney, 72 inches internal diameter.

The standard engine house, 50x140 feet, contains an Allis-Chalmers, duplex, 28 inch x 60 inch first motion hoist connected to one drum 12 feet in diameter with 12 foot face operating two 5 ton skips in balance, also an Allis-Chalmers 24 inch x 48 inch duplex hoist geared to one drum 12 feet diameter with 12 foot face operating the cage.

GENEVA.

This is an exploration of the Oliver Iron Mining Company and joins the Davis on the east. The shaft is 2,190 feet deep. The boiler house contains three 60x16 ft. and one 72x16 ft. return tubular boilers. The engine house contains a 28x60 Corliss hoisting engine geared to one drum 10 ft. diameter with 66 inch face operating one skip for development work.

PURITAN.

The Puritan joins the Geneva on the east and is operated by the Oliver Iron Mining Company; will be among the shipping mines for this season. It is operated through one shaft 1,260 feet deep. The standard boiler house 50x52 ft. contains four 72x18 ft. horizontal return tubular boilers with a tile chimney 125 ft. high and 66 in. inside diameter. The standard engine house 50x74 ft. contains one 28x60 Sullivan first motion hoisting engine connected to one drum 12 ft. diameter with 12 ft. face operating one 4 ton skip and one cage, also 100 K. W. direct current generator driven by a 14x36 Nordberg Corliss engine.

THE IRONTON.

The Ironton joins the Puritan on the east, is operated by Corrigan, McKinney & Co. There are two shafts, No. 3 and No. 4, only No. 4 being at the present used for hoisting ore. No. 3 is used as a timber shaft and for ventilation. In No. 4, two 3 ton skips are operated in balance. A cage is operated instead of one skip, being put on at the 15th level when needed. Depth of shaft is 1,350 feet, being bottomed at the 17th level. The hoisting is done from the 13th and 15th levels. The 17th level is now being opened but no ore has yet been found. Electric locomotives are on the 13th and 15th levels. The surface equipment consists of a 25-drill Franklin cross compound air compressor, one Sullivan first motion two drum hoist, a 75 K. W. Jeffery generator driven by McKewen engine. Steam is furnished by five 150 H. P. horizontal return tubular boilers.

YALE.

The Yale adjoins the Ironton on the east and is operated by the Ashland Iron & Steel Company. It is operated through one shaft 1,915 feet deep. Boiler house contains four 72x18 horizontal return tubular boilers. The mechanical equipment consists of a 20x42 Sullivan Corliss hoisting engine geared to

8 ft. drum and a 16-28 & 24-14½x24 Sullivan-Tandem compound Corliss air compressor.

THE COLBY.

The Colby lies east of the Yale. It is operated by Corrigan, McKinney & Co. This is the pioneer mine of the range and in the early operation was the largest producer. The first discovery of ore on the range is said to have been made here in 1880 by Capt. N. D. Moore. It is claimed the real discoverer was Richard Langsford, a woodsman, who informed Capt. Moore of its location. The original ore body came to surface and was mined open pit. The Colby is still a regular producer but the present ore body is much narrower than the original discovery. Three shafts are operated, No. 1, No. 2 and No. 6, their depths being respectively 1,600 feet, 1,650 feet and 500 feet. A cage is operated in No. 2 shaft only. No. 6 is a new shaft this year, situated 500 feet north of the foot wall, and was put down to serve an upper working of the Colby north vein. The foot wall vein in this mine has been found very narrow and is not being worked. The present production is obtained from the 4th, 9th and 11th levels. Mules are used on these levels for tramming. Surface equipment consists of 10 ft. tandem drum hoist and 25 drill Imperial Rand air compressor at No. 1, and a first motion 7 ft. drum Sullivan skip hoist and a Sullivan 8 ft. geared cage hoist at the No. 2. Steam is furnished by five 150 H. P. horizontal return tubular boilers.

TILDEN.

The Tilden joins the Colby on the east; is operated by the Oliver Iron Mining Company. The Tilden has been a large producer. The present showing in the bottom openings is not very encouraging. It is operated through three shafts, all sunk in the ore formation, No. 6, 1,440 feet deep, No. 9, 670 feet deep and No. 10, 960 feet deep. Each shaft is supplied with an independent equipment with a central compressor plant. No recent changes or additions have been made to the equipment.

PALMS.

The Palms adjoins the Tilden on the east. This is not at present producing.

ANVIL.

The Anvil lies next east of the Palms. Both are owned by the Newport Mining Company.

THE EUREKA.

The Eureka lies next east of the Anvil. This is operated by Ogelbay, Norton & Co. It has two working shafts, No. 2, 1,181 feet deep, and No. 3, 1,347 feet deep. The boiler house contains four 72x18 horizontal return tubular boilers. No. 2 shaft is operated by a 20x42 Sullivan Corliss hoist geared to an 8 feet drum. No. 3 shaft is operated by a 14x20 National Iron Company geared hoist with a 6 ft. drum. Compressed air is furnished by a 20-13½ & 12-22x24 Norwalk air compressor.

THE ASTEROID.

Lies east of the Eureka and is an exploration of Oglebay, Norton & Co. The shaft is 964 feet deep. The boiler plant consists of two 150 H. P. Babcock & Wilcox water tube boilers and two 72x18 horizontal return tubular boilers. The mechanical equipment consists of a 14x20 National Iron Co. geared hoist with a 6 ft. drum, a 16-28 & 24-14½x24 Sullivan Tandem compound Corliss air compressor.

THE MIKADO.

The Mikado joins the Asteriod on the east. It is operated by Pickands, Mather & Co. The boiler house contains two 72x16 ft. and two 66x16 ft. horizontal return tubular boilers. There are two shafts, only one, No. 2, 950 feet deep being operated. The mechanical plant consists of a Wellman-Seaver-Morgan 20x42 first motion hoist operating two independent drums 6 ft. diameter with 6 ft., 6 in. face, and a Sullivan straight line air compressor.

THE BROTHERTON.

The Brotherton, two miles east of the Mikado, is the next active mine and is operated by Pickands, Mather & Co. The main hoisting shaft is steel lined, 6x16 ft., 1,200 feet deep. The boiler house, 45x55 ft., contains three 72 in.x18 ft. horizontal return tubular boilers. The engine house contains a Wellman-Seaver-Morgan first motion duplex 20x 42 hoist connected to a 7x9 ft. drum operating two 3 ton skips in balance.

THE SUNDAY LAKE.

The Sunday Lake joins the Brotherton on the east. It is operated by Pickands, Mather & Co., has one main hoisting shaft, No. 6, 1,200 feet deep. The boiler house, 45x65, contains four 72x18 ft. horizontal return tubular boilers. The engine house contains a 20x42 Wellman-Seaver-Morgan duplex direct connected hoist operating two 2-ton skips in balance and a 15 drill Ingersoll-Rand cross compound air compressor.

THE CASTILE.

The Castile joins the Sunday Lake on the east and is the most easterly producing mine on the range. The working shaft is 1,342 feet deep. The boiler house contains three 72x18 horizontal return tubular boilers. The mechanical equipment consists of a 14x20 National Iron Company hoist with a 6 ft. drum and a 16-28 & 24-14½x24 Sullivan tandem compound Corliss air compressor. It is operated by Oglebay, Norton & Co.

GERMANIA.

Beginning at the Ashland mine and crossing the Montreal river into Wisconsin, the first mine is the Germania, operated by the Harmony Iron Company. Exploring has been carried on here since 1900 without proving any large body of ore. The exploring shaft is 1,884 feet deep.

THE CAREY.

The Carey lies next west of the Germania and is operated by Pickands, Mather & Co. There are four shafts sunk in the ore on the foot wall, No. 1, 1,200 feet deep, No. 4, 780 feet deep, No. 5, 1,160 feet deep and No. 6, 730 feet deep. No. 1 boiler house contains three 72 in. x 18 ft. horizontal return tubular boilers. The engine house contains a Wellman-Seaver-Morgan 20x48 duplex first motion hoist connected to an 8 ft. diameter, 9 ft. face drum operating one 2 ton skip.

No. 5 boiler house contains four 72x18 ft. horizontal return tubular boilers. The engine house contains a single cylinder 22x42 Wellman-Seaver-Morgan hoist geared to two independent drums 8 ft. diameter, 9 ft. face, and an 18 & 34x36 steam, 19 & 29x36 Ingersoll-Rand air compressor.

THE OTTAWA.

Lies next west of the Carey. Is operated by Oglebay, Norton & Co. It has two working shafts, No. 1, 698 feet deep, and No. 3, 681 feet deep. No. 1 boiler house contains two 150 H. P. vertical Wickes water tube boiler. No. 3 boiler house contains two 150 H. P. vertical Wickes water tube boilers. The mechanical equipment consists of an 18x 36 Webster, Camp & Lane hoist geared to two 5 ft. drums and a 14-26 & 24-15x30 Laidlaw-Dunn-Gordon cross compound Corliss air compressor.

THE MONTREAL.

Lies next west of the Ottawa and is operated by Oglebay, Norton & Co. It contains two working shafts, No. 3, 1,915 feet deep, and No. 4, a new foot wall, steel lined shaft, 2,150 feet deep. No. 3 boiler plant contains three 150 H. P. Wickes, two 150 H. P. Babcock & Wilcox water tube boilers and one 150 H. P. Sterling water tube boiler. The mechanical equipment at No. 3 shaft consists of a 20x42 Bullock Corliss hoist, geared to two 6 ft. drums operating the cages, and a 22x48 Bullock first motion Corliss hoisting engine connected to two 7 ft. drums operating the skips, and an 18x42 Ingersoll-Sargent duplex Corliss air compressor. The equipment of No. 4 shaft consists of three 227 H. P. Rust water tube boilers, one 24x48 Sullivan geared Corliss hoisting engine connected to one 10 ft. drum, and a 16-28 & 24-14½x24 Sullivan tandem compound Corliss air compressor.

HENNEPIN.

Hennepin, Pence & Snyder are explorations of Jones & Laughlin Co., west of the Montreal.

PLUMER.

The Plumer, an exploration shaft of the Oliver Iron Mining Co., is the next active property west of the Snyder. The shaft is steel lined, 1,340 feet deep. The standard boiler house, 50x52 contains four 72x18 ft. horizontal return tubular boilers with tile chimney 125 feet high, 72 inches internal diameter. The standard engine house, 48x48, contains a Sullivan 28x60 first motion hoist direct connected to a 12 ft. diameter 12 ft. face drum operating two cages with 4 ton skips hung beneath.

ATLANTIC.

The Atlantic lies next west of the Plumer and is operated by the Oliver Iron Mining Co. Has two shafts, No. 2, 1,060 feet deep, and No. 3, a vertical hanging wall shaft 1,210 feet deep. The equipment at No. 3 is a standard boiler house with four 72x18 ft. horizontal return tubular boilers. The engine house contains a single, reversible, Wellman-Seaver-Morgan 20x48 Corliss hoisting engine geared to one drum 9 ft. diameter with 8 ft. 6 in. face operating two 5 ton skips in balance, a 20x48 Wellman-Seaver-Morgan, single non-reversing hoist geared to one 9 ft. diameter drum with 8 ft. 6 in. face, operating the cage, and an Allis-Chalmers 17 & 24x36 steam 16 & 26x36 Corliss air compressor. This is the most westerly producing mine on the range.

IRON BELT.

The Iron Belt joins the Atlantic on the west and has been a regular producer until this season. It is now closed and abandoned, the ore body having been exhausted.

SHIPMENTS.

With the exception of the Mesaba Range, the Gogebic is the last to enter the list of iron ore producing districts of the Lake Superior region. The first shipment of ore from this range was made in October, 1884. The shipments in 1909 were 4,088,057 tons, being the largest in the history of the range to date. This production was distributed as follows:

Anvil	22,927
Ashland	259,612
Atlantic	124,845
Aurora	144,631
Brotherton	103,090
Carey	224,251
Castile	26,982
Colby	170,095
East Norrie	470,119
Eureka	115,662
Germania	152
Iron Belt	44,560
Ironton	277,594
Mikado	99,195
Montreal	191,611
Newport	1,008,354
Norrie	182,317
Ottawa	100,223
Pabst	179,987
Pike	22,174
Sunday Lake	93,712
Tilden	154,506
Yale (West Colby)	71,458
Total	4,088,057
Total to date	60,820,503

Mines Not Producing in 1909.

Chicago,	Hennepin,	Palms,
Davis,	Jack Pot,	Puritan,
Geneva,	Meteor,	Shores.

SELLING PRICE OF IRON ORE AND PRICE OF PIG IRON AT DATE OF BUYING MOVEMENT

Season	Date Buying Movement	Season Iron Ore Prices O. R. Bes.	Mes. Bes.	O. R. non-B	Mes. non-B.	Iron Prices, Bess.	Valley No.2 Fdy.
1890	Dec. 15, '89	$5.50	no sale	$5.25	no sale	$22.15	$18.15
1891	June 1, '91	4.50	no sale	4.25	no sale	15.15	15.00
1892	Jan. 31, '92	4.50	no sale	3.65	no sale	16.40	13.65
1893	March 15, '93	3.85	$3.00	3.20	no sale	12.65	12.15
1894	March 1, '94	2.75	2.35	2.50	no sale	9.65	9.65
1895	April 1, '95	2.90	2.15	2.25	$1.90	9.40	9.40
1896	May 1, '96	4.00	3.50	2.70	2.25	12.40	11.15
1897	May 20, 97	2.60	2.25	2.15	1.90	8.35	8.40
1898	March 20, '98	2.75	2.25	1.85	1.75	9.55	9.80
1899	Feb. 1, '99	3.00	2.40	2.15	2.00	10.30	9.75
1900	Dec. 15, '99	5.50	4.50	4.25	4.00	24.15	22.15
1901	April 15, '01	4.25	3.25	3.00	2.75	16.15	14.40
1902	Feb. 1, '02	4.25	3.25	3.25	2.75	15.90	15.90
1903	March 20, '03	4.50	4.00	3.60	3.20	21.50	21.65
1904	April 15, '04	3.25	3.00	2.75	2.50	13.35	13.15
1905	Feb. 1, '05	3.75	3.50	3.20	3.00	15.50	16.00
1906	Dec. 5, '05	4.25	4.00	3.70	3.50	17.25	17.25
1907	Nov. 10, '06	5.00	4.75	4.20	4.00	21.50	21.50
1908	June 15	4.50	4.25	3.70	3.50	16.00	15.00
1909	May 10	4.50	4.25	3.70	3.50	14.75	14.25
1910	Feb. 15	5.00	4.75	4.20	4.00	16.25	14.75

[Iron Trade Review]

THE FIFTEENTH ANNUAL MEETING.

WEDNESDAY, AUGUST 24TH, 1910.

It was in the City of Ironwood, on February 2nd, 1893, that the Lake Superior Mining Institute had its inception at a social gathering of mining men from the Gogebic and Menominee ranges. There were forty present at this meeting at which committees were appointed to discuss the idea among the men of the other ranges, with a view to forming a permanent organization. During the seventeen years which have intervened since this first gathering, many very pleasant and profitable meetings have been held on the various ranges. Many changes have been made in equipment and mining methods since that time. This is very noticeable on the Gogebic Range which has improved steadily in the surface and underground equipment and the product has increased from 1,329,385 tons in 1893 to 4,088,057 tons in 1909. The first shipment was made in 1884.

The present list of mines, their location and other information of interest together with the program, was printed for this meeting and the same with the committees and itinerary of the trip, is published herewith. As only one day was to be devoted to the mines, those of Ironwood and Bessemer alone were visited, rain in the afternoon interfering with the visit planned to the mines at Wakefield.

MINUTES OF MEETING.

WEDNESDAY, AUGUST 24TH, 1910.

EVENING SESSION.

The evening session was held at the Pierce Theater at 8 o'clock and was attended by two hundred members and guests.

Many of the citizens were present among whom were a number of miners. The Ironwood band played several selections during the evening. Mr. Sutherland, President of the Institute being absent for the evening, the meeting was called to order by Mr. John M. Bush, Vice President. In opening the meeting, Mr. Bush spoke in part as follows:

In behalf of the Institute and the citizens of Ironwood, I welcome you to the 15th annual meeting of the Lake Superior Mining Institute.

You have seen our mines and the community surrounding them and I trust your visit to both has been worth while. We, of the Gogebic Range, have made some progress since you were last here six years ago. We are hopeful of doing better things in the future, industrial and otherwise. I am sure that you are agreeably anticipating the trip to Chicago and Gary and I believe that portion of the program will both please and instruct you.

My wish is that you may be returned to your homes without mishap, that you will have had an enjoyable time and that you will want to come to Gogebic Range again. It is with pleasure that I introduce Judge Samuel S. Cooper of this city, who will deliver the address of welcome.

ADDRESS OF WELCOME—BY HON. S. S. COOPER, IRONWOOD, MICH.

Gentlemen of the Institute: Ironwood wishes to express to the Lake Superior Mining Institute a most hearty welcome. It is a pleasure to receive a visit from the members of this association. In this mining country we are indebted to the mining industry for our thriving communities and our prosperous people. Whatever is a benefit to the mining industry, is a benefit to the community, and all things which tend to the advancement and improvement of the mining town are bound to result in good to the carrying on of the mining business. In no other place has this fact been more thoroughly appreciated than in this city, which has had the honor of your company today. For a decade, the people of our city have kept at the head of their municipal affairs as mayor, the honored president of your association, Captain Sutherland, and they have done so practically by unanimous consent. In this manner, and in many other ways, they have expressed their appreciation of the fact that it is for the mutual benefit of the mining industry and the people of the community that they should work together with their shoulders to the one wheel pushing for the benefit of both, because the success of the one is sure prosperity for the other. I need not dwell upon results, you have seen our city: Prosperity shines forth from its every nook and corner, as well as from the faces of its people. Some years ago you will remember, when the great Mesaba Range was discovered, we were told that the Gogebic might prepare to go out of business. Today you have partly looked us over and you have seen that we are still very actively engaged in business, indeed, you have found us in a more prosperous condition than you have ever seen us before. Many of you have dwelled with us in years gone by and we have been particularly glad to greet you and demonstrate to you that the old Gogebic is still among the living and will live to see many generations of people yet to come. As we have appreciated the necessity of community of interest between the mining companies and the mining communities, so do we realize the importance of peace and good will between the various mining interests, and again we can point with delight to the unbroken harmony existing between the various mining interests throughout the entire Gogebic Range. There is nothing which tends to strengthen this excellent feeling among such interests more than your splendid institute. I am sure that more benefits have grown directly out of your annual meetings than any of us can realize. The entire mining country should rejoice in having such an excellent organization to work for its general good. The people of Ironwood and the Gogebic Range are honored in having this opportunity of welcoming you. We are sorry that you are not to remain with us longer, for we are sure that there are many other items of interest that we could show you, but we hope, in the general course of events, to have you with us again at some time in the future and we assure you that you will always find a most hearty welcome. We have rejoiced, indeed, in having your company here today; we hope you will continue to prosper always; that you will continue to extend good fellowship among the people of the mining country; to exchange among yourselves advanced ideas in mining which you acquire from time to time in the prosecution of this important work, with a view of making it more safe for those who are employed in and about the mines, which should be, and I know is, one of your chief aims, as well as working for the general prosperity of the business. Gentlemen we welcome you.

The first paper of the evening was by John H. Hearding of Duluth, Minn., on "Reminiscences of the Early Days on the Gogebic Range," in which Mr. Hearding relates his interesting experience at Ironwood in 1887. Percival S. Williams, of Ramsey, Mich., presented a paper on "Underground Methods of Mining Used on the Gogebic Range," illustrating, by large drawings, the system known as top slicing. This paper brought out very interesting discussion. Doctor E. M. Libby, Iron River, Mich., read a very interesting paper, entitled "The Mine Surgeon." This concluded the reading of papers for the evening.

On motion the President appointed the following committees to report at the session the next evening at Gary, Indiana:

Committee On Nominations—L. C. Brewer, Ironwood, Mich; William Kelly, Vulcan, Mich.; Frank E. Keese, Ishpeming, Mich.; F. W. Sperr, Houghton, Mich.; Wm. J. West, Hibbing Minn.

Auditing Committee—Charles E. Lawrence, Iron Mountain, Mich.; William J. Smith, Mohawk, Mich.; F. J. Sullivan, Ironwood, Mich.

There being no further business, the meeting was adjourned. The special trains were in readiness at the Northwestern Station and the party started on the trip to Gary.

THURSDAY, AUGUST 25TH, 1910.

Arriving in Chicago at eleven o'clock, the trains were stopped at the Sullivan Machinery Company's plant on West Lake street where nearly an hour was spent in going through the various shops. From here the party was taken by automobiles furnished by the Sullivan Company, through the West Side parks to the plant of Joseph T. Ryerson & Son, 16th and Rockwell Streets, arriving there shortly after one o'clock. Luncheon was partaken of in the dining room on the fourth floor where two hundred and fifty members and guests were served to a very substantial meal prepared by the Company's employees. An orchestra furnished music throughout the luncheon. Following this, a tour of inspection was made through the warehouses and shops which make the plant the largest and most complete of its kind in America. Again taking the automobiles the party proceeded to the National League ball park where, as guests of the Chicago members of the Institute, a game between the "Cubs" and "Giants" was witnessed.

At eight o'clock the party arrived at Gary where the second meeting was held at Assembly Hall, Sixth avenue and Broadway, President D. E. Sutherland, presiding. The first paper presented was by R. B. Woodworth, on "Underground Steel Construction, Particularly Mine Shafts." This paper was furnished to members in advance and in presenting it at the meeting Mr. Woodworth spoke as follows:

"It gives me great pleasure to present a paper to the Lake Superior Mining Institute on the subject of underground steel construction. This pleasure is twofold; first, my interest in the subject itself, and second, my interest in and friendship for the men who compose your Institute. The paper was written at the instance of one of the general superintendents of the Oliver Iron Mining Company, and it is to the members of this Institute that I owe in large measure the knowledge which I possess of underground mining operations when applied to the winning of ores. I present the paper, therefore, not only with a sense of pleasure, but in part as a small recompense for the obligations I am under. In a very large sense the uses of steel deserve the attention of those whose special business it is to mine the ores, as the man who digs iron ore has as much real and vital interests in the uses to which that ore is put as the man who actually makes and sells the steel. We have passed beyond the stage when we consider only our own share in any industry. To have an intelligent appreciation of all that really concerns ourselves, we must know not only the sources from which the material is drawn, but also the uses to which that material is put.

The paper falls into three natural divisions; first, a consideration of the unfitness of wood to be a perfect mine timbering material, and second, a demonstration of the peculiar fitness of steel for mine timbering purposes based not only on theoretical considerations, but on the results of wide experience not only in this country but abroad. In the third or descriptive portion are assembled a few selected examples properly classified by types of the uses of steel in level headings as well as in mine shafts, which examples will prove worthy of careful study as a guide to the problems which you may have to meet in the actual exploitation of our mineral resources. As a preliminary to the examples of steel shaft construction you will find some considerations of a technical nature dealing with the character of the stresses which are to be met with in mine timbering, also some items describing the advantages and disadvantages of different kinds of shafts, and an examination of the fitness of materials, such as wood, steel, concrete and brick for each type.

I think that we are beginning to learn in America that there is much profit for us in the experience of others, for experience, after all, is a great teacher, and while the conditions in ore mining are in some respects quite different from those employed in the mining of coal, and while American mining methods are in some respects quite sharply distinct from those in vogue abroad, yet we can still learn lessons of great value to us by this discussion of what others have done under conditions, after all, not so very diverse. I will admit that there are many things in underground timbering which are not yet reduced to an exact science and which perhaps are not yet irreducible to exact terms. These uncertainties, in my mind, do not in any way apply either to the fitness of steel for mine timbering purposes or to the kind of steel which ought to be employed in shaft lining, or to the future of steel as a mine timbering material. I will appreciate it very much if any members of the Institute will criticise fully those points on which their opinions may differ; and if any superintendent, engineer or mine captain does not care to have his remarks on this subject printed in a formal way in the Proceedings of the Institute, I will very much appreciate it if you will give me your criticisms by letter.

MR. WILLIAM KELLY—I want to compliment the gentleman on his paper. It is the most comprehensive statement that I have seen on the subject of steel framing and concrete work. He cites numerous instances both in this and in foreign countries and gives us most valuable ideas as to modern practice. The Institute can be proud of the papers that have been presented to it on this subject. We have had several papers describing particular cases of steel framing, and two on concrete construction. There is only one point in the paper on which I would like to take issue and that is the statement in regard to the comparative efficiency of a circular and a rectangular section for shafts. In the first place I would urge the theoretical consideration that with a circular section the lining is under nearly uniform compression, while with rectangular construction that is not likely to be the case and secondly the object of a shaft is not solely to provide space for cages and skips but other spaces are required for ladder roads and for pipes. With a circular section the irregular corners that are left can very well be utilized for these minor purposes and therefore I believe that in a great many cases a circular section would be found to be quite as economical as a rectangular one.

The paper by Chas. S. Hurter, on "The Proper Detonation of High Explosives" was distributed in printed form and presented by the author. This brought out considerable discussion and the same is published, following the paper, in another part of the proceedings.

The following papers were presented by title and are published in this volume:

A Diamond Drill Core Section of the Mesaba Rocks (Part II), by N. H. Winchell, Minneapolis, Minn.

Steel Head Frame, No. 4 Shaft, Montreal Mine, by Frank B. Goodman, Hurley, Wis.

The Newport Mine, by Luther C. Brewer, Ironwood, Mich.

At the conclusion of the reading of papers and discussions, the Council presented its report for the fiscal year closing August 26th, 1910.

REPORT OF THE COUNCIL.

The Secretary's report of Receipts and Disbursements from August 25th, 1909 to August 26th, 1910, is as follows:

RECEIPTS.

Cash on hand August 25th, 1909			$4,509.55
Entrance fees for 1909	$ 220 00		
Dues for 1909	1,985 00		
Back dues	225 00		
Advance dues, 1910	55 00		
Sale of Proceedings	92 20		
Sale of Institute Badges	12 00		
Total		$2,589 20	
Interest on deposit		164 09	
Total receipts			2,753 29
Grand total			$7.262 84

DISBURSEMENTS.

Stationery and printing	$ 95 65		
Postage	140 81		
Freight and express	18 44		
Telephone and telegraphing	1 68		
Secretary's salary	750 00		
Stenographic work	66 50		
Total		$1,073 08	
Publishing Proceedings, Volume XIV	$ 759 50		
Photographs, maps, etc	116 46		
Total		$ 875 96	
Badges for meeting, 1910	78 25		
Entertainment meeting, 1909	159 00		
Total		237 25	
Total disbursements			2,186 29
Cash on hand, August 25th, 1910			5,076 55
Grand total			$7,262 84

MEMBERSHIP.

	1910.	1909.
Members in good standing	465	475
Honorary members	4	4
Life members	2	2
Members in arrears (2 years, '08-'09)	36	36
Total	507	517
New members admitted	45	72
New members not qualified	1	1
New members added	44	71

TREASURER'S REPORT.

The Treasurer's report from August 25th, 1909 to August 26th, 1910, is as follows:

Cash on hand August 25th, 1909	$4,509 55	
Received from Secretary	2,589 20	
Interest on deposits	164 09	
Paid drafts issued by the Secretary		$2,186 29
Cash on hand August 26th, 1910		5,076 55
Totals	$7,262 84	$7,262 84

Your committee appointed to examine the books of the Secretary and Treasurer, beg leave to report that we have carefully examined same and find that the receipts and expenditures shown therein to be in accordance with the above statement for the fiscal year ending August 24th, 1910.

WILLIAM SMITH,
CHAS. E. LAWRENCE,
F. J. SULLIVAN.

The following applications for membership have been received since the last annual meeting and are approved by the Council:

Abeel, Geo. H. Jr., Assistant Superintendent, Wakefield, Mich.

Allen, R. C., State Geologist, Lansing; Mich.

Baird, Alexander, Salesman, C. P. .T. Co., 1010 Fisher Bldg., Chicago, Ills.

Bretting, C. G., C. G. Bretting Mfg. Co., Ashland, Wis.

Campbell, D. H., Mine Superintendent, Iron River, Mich.

Crosby, Geo. H., Mines & Mineral Lands, Lonsdale Bldg., Duluth, Minn.

Davis, W. J., Asst. Supt. Mikado Mine, Verona, Mich.

Goodman, Frank B., Asst. Mngr. Montreal Mng. Co., Hurley, Wis.

Goudie, James, Mining Engineer, Ironwood, Mich.

Harwood, S. G., Draughtsman, Sherwood Bldg., Duluth, Minn.

Heggaton, William S., Mining Captain, Negaunee, Mich.

Heyn, Howard A., Salesman, Du Pont Pdr. Co., Ishpeming, Mich.

Hicks, Byron Wallace, Civil Engineer, Warren, Illinois.

Hill Stacy, Salesman, Ingersoll-Rand Co., Providence Bldg, Duluth, Minn.

Hodge, Richard, Gen'l. Mining Captain, The Shenango Furnace Co., Hibbing Minn.

Holley, Albert B., Mechanical Engineer, Virginia, Minn.

Holthoff, Henry C., Mining Engineer, 254 Nasau St., Milwaukee, Wis.

Hore, Reginald Edwin, Geologist, M. C. M., Houghton, Mich.

Howe, Geo. T., Lumberman, Ironwood, Mich.

Hurter, Chas. S., Technical Representative, Du Pont Powder Co., 314 Lyceum Bldg., Duluth, Minn.

Jackson, Frank W., Salesman, H. Channon Co., Market and Randolph Sts., Chicago, Ills.

Jopling, Morgan W., Lake Shore Engine Works, Marquette, Mich.

Kennedy, Frank A., Civil Engineer, The Shenango Furnace Co., Hibbing Minn.

Libby, Edward M., Physician and Surgeon, Iron River, Mich.

Loomis, A. J., Chemist, The Shenango Furnace Co., Hibbing, Minn.

Lukey, Frank, Mining Captain, Hurley, Wis.

McCorkindale, W. J., Mngr. Marquette County, Gas & Electric Co., Ishpeming, Mich.

McCormick, Edward, Mining Engineer, Buhl, Minnesota.

McLaughlin, Warren John, Mining Engineer, Loretto, Mich.

Reynolds, Maxwell K., Civil Engineer, Marquette, Mich.

Roberts, Alton T., Real Estate, Marquette, Mich.

Schlesinger, H. J., Vice President, Newport Mng. Co., Milwaukee, Wis.

Sheldon, Albert T., Salesman, Garlock Pkg. Co., Marquette, Mich.

Sill, Geo. A., United Globe Rubber Mfg. Co., 504 Marquette Bldg., Chicago, Ills.

Smith, Carl G., Mining Engineer, Montreal, Wis.

Smith, Alfred L., Mining Engineer, Brotherton Mine, Wakefield, Mich.

Tancig, A., Mechanical Supt., The Shenango Furnace Co., Hibbing, Minn.

Taylor, James Hall, Gen. Mngr. American Spiral Pipe Works, Box No. 485, Chicago, Ills.

Trevariranus, George, Supt. Docks, D. M. & N. R'y., Duluth, Minn.

Turner, Charles N., Traffic Manager, Newport Mining Co., 216 Colby-Abbott Bldg., Milwaukee, Wis.

Vilas, P. M., Sales Agent, American Brake Shoe & Foundry Co., No. 425 N. Y. Life Bldg., Minneapolis, Minn.

Wengler, Matt P., Mechanical Engineer, Allis-Chalmers Co., 1055 Cambridge Ave., Milwaukee, Wis.

Whiteside, John Wyman, Mine Surgeon, Ironwood, Mich.

Willey, Norman W., Supt., The Shenango Furnace Co., Hibbing, Minn.

Wilson, Eugene B., Editor, Mines & Minerals, Scranton, Penn.

Woodworth, Robert Bell, Engineer with Carnegie Steel Co., 427 Carnegie Bldg., Pittsburg, Pa.

On motion, duly carried, the Secretary was instructed to cast a ballot for the election of the applicants to membership.

Your committee on nominations beg leave to submit the following names as officers of the Institute for terms specified:

For President (one years):

Wm. J. Richards, Crystal Falls, Mich.

For Vice Presidents (two years):

E. D. Brigham, Chicago, Ills.
Chas. H. Munger, Duluth, Minn.

For Managers (two years):

Peter Pascoe, Republic, Mich.
Jas. B. Cooper, Hubbell, Mich.
L. C. Brewer, Ironwood, Mich.

For Treasurer (one year):

E. W. Hopkins, Commonwealth, Wis.

For Secretary (one year):

A. J. Yungbluth, Ishpeming, Mich.

L. C. BREWER,
WILLIAM KELLY,
FRANK E. KEESE,
F. W. SPERR,
WM. J. WEST,
Committee.

The report of the Committee was on motion unanimously adopted and the Secretary instructed to cast a ballot for the election of the officers as presented.

The following resolution was presented by C. E. Lawrence and on motion unanimously adopted:

Resolved, That a vote of thanks be extended by the Institute to the Mining Companies of the Gogebic Range and their local officials, for the entertainment offered on the occasion, of its third visit; also to the citizens of Ironwood for their cordial reception; to the Railroad Companies for the exceedingly good service given in the movement of the members in special trains; and to the members on the Reception Committee in Chicago and to the officials of the Indiana Steel Company, for the many courtesies and privileges shown its members and guests during the trip.

The following is a partial list of those in attendance:

ALLEN, R. C............................Lansing, Mich.
ABEEL, GEO. H. JR....................Ironwood, Mich.
ABEEL, JOHN H.......................Ironwood, Mich.
ABEEL, GEO. H........................Ironwood, Mich.

BALDWIN, C. KEMBLE...................Chicago, Ills.
BISHOP, J. A..............................Antigo, Wis.
BRIGHAM, E. D..........................Chicago, Ills.
BRIGHAM, E. D. JR.....................Chicago, Ills.
BARD, W. P..............................Antigo, Wis.
BANFIELD, RICHARD ....Ironwood, Mich.
BLACKWELL, FRANK ....Ironwood, Mich.
BRENNAN, J. V........................Ironwood, Mich.
BLACKWELL, JAS.. ....Ironwood, Mich.
BREWER, L. C.........................Ironwood, Mich.
BENNETT, C. E........................Ironwood, Mich.
BREWER, GEORGE ....Ironwood, Mich.
BREKLIN, H. F..........................Antigo, Wis.
BRETT, HENRY ....Calumet, Mich.
BRETT, HENRY JR................San Francisco, Cal.
BAIRD, ALEXANDER ....Chicago, Ills.
BREWER, CARL ....Ishpeming, Mich.
BUMSTEAD, DALE ....Chicago, Ills.
BOLLES, F. G........................Milwaukee, Wis.
BUSH, JOHN M.......................Ironwood, Mich.

CONOVER, A. B.........................Chicago, Ills.

COPELAND, FRANK ....Vulcan, Mich.
CARR, C. M..............................Chicago, Ills.
CARTER, R. B...........................Chicago, Ills.
CHINN, WM. P........................McKinley, Minn.
COOPER, JAS. B.........................Hubbell, Mich.
CAMPBELL, D. H....................Iron River, Mich.
CLEMENS, JOHN ....Ishpeming, Mich.
CONNELL, E. P.......................Marquette, Mich.
CURRY, GEO. A.......................Ironwood, Mich.
CARBIS, FRANK ....Iron Mountain, Mich.
CARROLL, M. J........................Houghton, Mich.
CONNORS, THOS..... ....Negaunee, Mich.
CLARK, E. G.......................Minneapolis, Minn.
COLE, W. A.............................Ironwood, Mich.
CUMMINGS, P. H.....................Ironwood, Mich.
COLE, C. D............................Ishpeming, Mich.
CHAMBERLAIN. P. F....................Tower, Minn.
COLE, WM. T..........................Ishpeming, Mich.
CLARK, G. R...........................Virginia, Minn.
CLIFFORD, J. M.......................Escanaba, Mich.
CHAMPION, CHAS..... ....Beacon, Mich.
COOPER, S. S..........................Ironwood, Mich.

DUFF, HARRY E....................Iron River, Mich.
DAVIS, JOSEPH ....Ironwood, Mich.
DEAN, DUDLEY S........................Boston, Mass.
DEVOY, JAMES ....Ironwood, Mich.
DURKEE, C. L..........................Ashland, Wis.
DAVIS, WALTER C....................Ironwood, Mich.
DOUGLAS, R. A........................Ironwood, Mich.

EDWARDS, E. P..........................Chicago, Ills.
EATON, LUCIEN ....Ishpeming, Mich.
EVANS, H. W............................Chicago, Ills.
ERICKSON, GUST ....Ironwood, Mich.
ERICKSON, C. E......................Ironwood, Mich.

FRASER, W. H.....................Crystal Falls, Mich.
FOLEY, D. F...........................Virginia, Minn.
FISHWICK, E. T......................Milwaukee, Wis.
FESING, H. W........................Houghton, Mich.
FLODIN, NELS P......................Marquette, Mich.

GOODMAN, F. B.........................Hurley, Wis.
GIBBS, C. A...........................Houghton, Mich.
GRAVES, W. H..........................Chicago, Ills.
GUNSOLAS, F. G.....................Wilmington, Del.
GRIBBLE, S. J........................Ironwood, Mich.

HARDEN, J. H...........................Chicago, Ills.

HOUK, C. E............................Ironwood, Mich.
HAMILTON, W. C........................Chicago, Ills.
HEARLEY, M. T.........................Cleveland, Ohio.
HIGGINS, F. H.........................Virginia, Minn.
HEARDING, J. H........................Duluth, Minn.
HOLMAN, J. WINCHESTER..............Chicago, Ills.
HARDENBURGH, L. M....................Hurley, Wis.
HELMER, C. E..........................Escanaba, Mich.
HARRIS, S. T..........................Houghton, Mich.
HODGSON, J. H........................Ishpeming, Mich.
HEYN, H. A............................Ishpeming, Mich.
HEGGATON, WILLIAM ....Negaunee, Mich.
HERROTT, C.. ....Chicago, Ills.
HEDIN, AND. G........................Ironwood, Mich.
HOTCHKISS, W. O.....................Madison, Wis.
HARWOOD, S. G........................Duluth, Minn.
HOLLEY, C. E..........................Bessemer, Mich.
HOLLEY, A. B..........................Virginia, Minn.
HASTING, E. X........................Green Bay, Wis.
HUNTINGTON, G. R................Minneapolis, Minn.
HURTER, CHAS. S....................Ishpeming, Mich.
HILL, STACEY ....Duluth, Minn.
HOWE, GEO. T........................Ironwood, Mich.

JOPLING, M. W.......................Marquette, Mich.
JOPLING, R. M.......................Marquette, Mich.
JOPLING, J. E.........................Ishpeming, Mich.
JOHNSTON, W. H....................Ishpeming, Mich.
JORY, WM. ....Princeton, Mich.
JUSSIN, B. E..........................Ironwood, Mich.
JETTNER, A. R..........................Chicago, Ills.
JOHNSTONE, O. W...................Ironwood, Mich.

KLINGLUND, F. D.................Stambaugh, Mich.
KING, ROBERT ....Hurley, Wis.
KEARNEY, F. H.......................Ironwood, Mich.
KELLY, M.. ....Montreal, Wis.
KELLY, J. J............................Antigo, Wis.
KEESE, F. E..........................Ishpeming, Mich.
KEATING, W. J.......................Escanaba, Mich.
KAHN, D. A..........................Woodruff, Wis.
KOEPEL, ED..... ....Beacon, Hill, Mich.
KLEFFMAN, JOHN ....Hibbing, Minn.
KELLY, WILLIAM ....Vulcan, Mich.
KIND, THOS... ....Ironwood, Mich.

LAWRENCE, C. E...............Iron Mountain, Mich.
LOOK, WM. F......................Panama City, Fla.
LUNDQUIST, E. W...................Milwaukee, Wis.

LAING, V. D....................Iron River, Mich.
LESSELYONG, F. H....................Ironwood, Mich.
LONGYEAR, J. M....................Marquette, Mich.
LUKE, FRANK ....Hurley, Wis.
LAMBRIX, MICHAEL ....Hurley, Wis.
LINN, A. E....................Norway, Mich.
LETZ, JOHN F....................Milwaukee, Wis.

MACE, R. E....................Duluth, Minn.
MITCHELL, W. A....................Chicago, Ills.
MURPHY, N. D....................Watersmeet, Mich.
MOWATT, N. P....................Chicago, Ills.
MARS, W. P....................Duluth, Minn.
M'GEE, M. B....................Crystal Falls, Mich.
MATTACHECK, M. W....................Ironwood, Mich.
M'CORKINDALE, W. J....................Ishpeming, Mich.
MONROE, W. G....................Iron Mountain. Mich.
MOORE, R. E....................Chicago, Ills.
MITCHELL, S. J....................Marquette, Mich.
MINER, A. B....................Ishpeming, Mich.
MINOR, GEO. W....................Waukesha, Wis.
M'GREGOR, S. J....................Iron Mountain, Mich.
M'NAMARA, JOHN ....Ironwood, Mich.
M'KEVITT, THOS. L....................Ironwood, Mich.
M'DONALD, W. A....................Antigo, Wis.
M'LAUGHLIN, W. J....................Loretto, Mich.
MILLER, F. A....................Ironwood, Mich.
M'GONAGLE, W. A....................Duluth, Minn.
M'NEIL, E. D....................Virginia, Minn.
MURRAY, ROBERT ....Hibbing, Minn.
MARTIN, W. L....................Minneapolis, Minn.

NELSON, E. D....................Ironwood, Mich.
NEWETT, W. H....................Ishpeming, Mich.
NEWTON, C. A....................Chicago, Ills.

OLSON, C. E....................Ironwood, Mich.
OLSON, G. A....................Ironwood, Mich.
ORR, F. D....................Duluth, Minn.

PASCOE, PETER W....................Republic, Mich.
PATRICK, JOHN B....................Ironwood, Mich.
PRISSLER, M.. ....Chicago, Ills.
PATTERSON, C. L....................Wilmington, Del.
PATRICK, H. E....................Chicago, Ills.
PRESCOTT, FRED M....................Milwaukee, Wis.
POTTER, E. T....................Minneapolis, Minn.
PERKINS, S. J....................Ironwood, Mich.

QUIGLEY, G. J....................Antigo, Wis.

QUINE, JOHN T....................Ishpeming, Mich.

REEDER, C. T........................Chicago, Ills.
ROUGH, JAS. H....................Negaunee, Mich.
ROUGH, JAS. H. JR...................Negaunee, Mich.
RAISKY, F. H....................Ishpeming, Mich.
ROBERTSON, H. J....................Escanaba, Mich.
ROWE, NATHANIEL ....Ishpeming, Mich.
RALEY, R. J........................Duluth, Minn.
REDFERN, JOHN A....................Hibbing, Minn.
ROCKWOOD, D. E........................Antigo, Wis.
ROWE, W. C........................Bessemer, Mich.
ROWE, HENRY ....Ironwood, Mich.
RYLAND, A. J........................Antigo, Wis.
ROWE, JAMES ....Osceola, Mich.
ROBERTS, ENOCH ....Iron River, Mich.
RICHARDS, W. J..................Crystal Falls, Mich.
RICHARDS, W. J....................Painesdale, Mich.
RICHEY, E. W........................Chicago, Ills.
RICHARDS, M. E......................Virginia, Minn.
REYNOLDS, MAX K..................Marquette, Mich.
ROBERTS, A. T....................Marquette, Mich.

SHIELDS, I. J....................Houghton, Mich.
SIMPSON, W. S....................Wilmington, Del.
SELLS, MAX ....Florence, Wis.
SOADY, HARRY ....Duluth, Minn.
SISLEY, L. A........................Chicago, Ills.
SPERR, F. W........................Houghton, Mich.
STEVENS, F. J......................Ironwood, Mich.
SAVAGE, J. A........................Hibbing, Minn.
SIMMONS, CHAS... ....Champion, Mich.
SPROULE, EVERETT ....Chester, Pa.
SHELDON, ALBERT T................Marquette, Mich.
SKUD, ADOLPH ....Ironwood, Mich.
SPORLEY, C. L......................Negaunee, Mich.
SKINNER, M. B........................Chicago, Ills.
SAMPSON, JOHN ....Ashland, Wis.
STEVENS, ALBERT J..................Ironwood, Mich.
SHEA, M. C........................Calumet, Mich.
SPEAR, J. H........................Ironwood, Mich.
SMITH, C. G........................Montreal, Wis.
SUTHERLAND, D. E..................Ironwood, Mich.
STAKEL, C. J......................Ishpeming, Mich.
SIEBENTHAL, W. A..................Republic, Mich.
SHOVE, B. W........................Ironwood, Mich.

TAYLOR, J. H........................Chicago, Ills.
THOMAS, GRIFF ....Hurley, Wis.

TREBILCOCK, JOHN .... Ishpeming, Mich.
TURNER, C. N .... Milwaukee, Wis.
TRIPP, CHESTER D .... Chicago, Ills.
THOMAS, JOSEPH .... Negaunee, Mich.
TOLAN, WM.. .... Ironwood, Mich.
TRAVER, W. H .... Chicago, Ills.
TYLER, W. E .... Chicago, Ills.
TRUETTNER, I. W .... Bessemer, Mich.

UREN, DR. A .... Montreal, Wis.

VILAS, R. L .... Ishpeming, Mich.
VAN VALKENBURG, A. J .... Abbotsford, Wis.
VIVIAN, JAMES G .... Duluth, Minn.
VOGEL, FELIX A .... New York City.
VILAS, P. M .... Minneapolis, Minn.
VALLATT, B. W .... Ironwood, Mich.
VEHMEYER, C. H .... Chicago, Ills.

WHITE, WM... .... Virginia, Minn.
WHITESIDE, DR. J. W .... Ironwood, Mich.
WARE, J. F .... Dayton. Ohio.
WOODWORTH, R. B .... Pittsburg, Pa.
WEST, W. J .... Hibbing, Minn.
WELLS, HELMUS .... Milwaukee, Wis.
WELLS, PEARSON .... Ironwood, Mich.
WALLACE, R. B .... Republic, Mich.
WENGLER, M. B .... Milwaukee, Wis.
WARE, FRED .... Negaunee, Mich.
WOODWORTH, G. L .... Iron River, Mich.
WELLS, MACKEY .... Milwaukee, Wis.
WEELWRIGHT, O. W .... Florence, Wis.
WEBB, C. E .... Houghton, Mich.
WHITMAN, B. F .... Ironwood, Mich.
WILLIAMS, P. S .... Ramsay, Mich.

YOUNGS, F. W .... Iron River, Mich.
YOUNGS, D. M .... Iron River, Mich.
YUNGBLUTH, A. J .... Ishpeming, Mich.

UNDERGROUND STEEL CONSTRUCTIONS—PARTICULARLY MINE SHAFTS.

R. B. WOODWORTH, M. AM. SOC. C. E., ENGINEER WITH CARNEGIE STEEL COMPANY.

The timbering of mines is a subject which well merits the attention of mining engineers, mine owners and mine operators. The literature on it is not voluminous and what there is deals with specific instances rather than with fundamental principles. The conditions to be met with in underground work are quite different, it is true, from those which obtain on the surface where it is possible to calculate the loading and the stresses involved with mathematical correctness and yet the fundamental principles of a technical character are in essence the same. Correct principles of engineering design must govern the economic use of material.

In what literature there is on the subject of mine timbering there is almost no reference made to the use of steel. When some three years ago the writer made his first contribution to this literature he presented certain considerations largely of a theoretical nature covering its use in underground operations, in part, on the basis of experience in the use of steel in building and bridge construction above ground, and, in part, on the records of English and Continental mining practice. Since that date a number of very successful installations of steel have been made in the United States in underground mining operations, not only in the anthracite and bituminous coal mines but also in the iron and copper mines as well, which have corroborated the correctness of his general conclusions and confirmed him in the judgment that steel is the logical successor of wood for mine timber purposes.

There are four general considerations which have to do with the economical application of steel in underground mining operations and go far to explain the very existence of these recent installations and the attention which has lately been paid to its use:—

1. The practical exhaustion of timber economically available for mine timber purposes.

2. The gradual appreciation of the fact that wood is not an economical material for all conditions of underground use.

3. A more serious regard for protection from fire and the probable loss of life and property consequent thereon.

4. The general improvement in mining methods.

TIMBER CONSERVATION.

The first consideration of course does not apply everywhere with equal force and there is still in some localities an ample supply of timber in suitable sizes for mine timber uses contiguous to the place of use. It is true, however, that the larger sizes of mine timbers are much more difficult to obtain and that the character of the supply has almost everywhere deteriorated so that species of wood which years ago would not have been considered at all suitable for mine timber uses have now become the main reliance of the mines.

There is also this other feature in the timber problem: A wise conservation of our timber resources means the reservation of the best timber for the more delicate and particular purposes of the arts and industries. With the gradual exhaustion of the hard woods and the species of soft woods peculiarly adapted to architectural uses and to employment in the manufacture of furniture, etc., the cutting of such timber for baser uses is a sheer economic waste.

Doubtless timber will continue to be used in underground and above-ground mine timbering operations so long as any supply of any kind of timber is available at reasonable rates. True economy in the use of timber in mining operations demands, however, the prevention of waste wherever possible and much can be done towards its elimination by the employment in mine timber sets of just the quantity of timber absolutely necessary to do the work for which it is intended. At the same time the enormous quantities of timber consumed in the mines and the depletion of the timber supply economically available for mine timber purposes have beyond question been one of the considerations which have led to the investigation of other materials of construction for use in substitution for wood. This consideration of course became more crucial in England and on the Continent before it had attention in the United States and the more advanced stage of solution reached abroad to the problems of reforestation and timber supply conservation is in itself an obvious indication of the fact. It is natural also that the use of substitutes for wood in underground mining operations was first made abroad.

WOOD NOT A PERFECT MINE TIMBER MATERIAL.

It cannot be denied that wood is not a perfect material for mine timber uses under the conditions of temperature, humidity, etc., which are found within the mines. Its merits are many, chief among which have been its wide distribution with ease of access to place of use, its consequent cheapness and the simplicity with which it may be framed and fitted for service. It is well fitted to bear loads of the character which are met with in mine timber operations and even after these loads have been borne to the point of failure that failure is usually attended by such signs of distress as to warn the miner of danger.

The defects of wood for mine timber purposes are well marked. The compressive strength of timber is greater than its tensile strength and there is absolutely no technical reason why the legs of the square timber set, for example, should always be the same size as the collar. In swelling ground the full strength of the legs may ultimately be developed and squeezes caused by adjustment of stresses under geologic forces may impose upon them loads which they are unable to sustain. The usual method of use, however, is always such as to follow that method of construction and difficulties from shearing stresses, etc., would arise if the legs and collars were made of different sizes so that in ordinary practice much more timber goes into the mines than would be necessary in the use of a material possessing more flexibility.

Besides the economic waste due to the size of timbers employed a certain amount of waste in framing must be expected and it is conservatively estimated that 10% of all the material going into underground operations is wasted and lost in the process.

More serious, however, than these defects is the liability of timber to decay under temperature and moisture conditions or to destruction by insect and bacterial action. Estimates of the United States Department of Agriculture Forest Service Bureau to the effect that 10% of all the mine timber is destroyed by insect action and 45% by decay produced by bacterial and fungous action do not seem excessive, especially in view of known experience in the deep workings of the anthracite coal fields. Insect action may be eradicated to a large extent by proper peeling and seasoning of the timber before it is placed in the mines; the removal of the bark, however, does not eliminate the loss of material by fungus action, for wherever moisture and heat coexist within the mines the fungus agencies of decay do their destructive work and the spores of the fungus can no more be eradicated than we can filter and sterilize the entire atmosphere. This condition is not serious in all mines and yet its existence in almost every mine is the ground for the science of preservative treatment as applied to mine timbers and the very fact that in many instances the life of the timber is extremely short without such preservative treatment is in itself a demonstration of the unsuitability of timber for mine timbering purposes.

The low strength particularly of certain kinds of timber when compared with other materials is also another item which must be considered in a discussion of the merits and demerits of wood. If another material of construction may be substituted for it which will reduce the amount of excavation necessary, then the first cost of heading or shaft work may likewise be reduced. Even in level workings where the excavated material is made up of ore or coal and after removal placed on the market for sale, the reduced size of the timber means better ventilation. This point was noted very early in the history of the use of steel within the mines of England and on the Continent and is a thing which is at once apparent when installations of steel mine timbers are inspected. In addition to this it is very apparent that if a material can be provided of much less weight in proportion to its strength its use will lead to cheapness in erection and therefore to reduction in first cost and maintenance inasmuch as all the timber for the work within the mines has either to be handled down the shaft or over the tracks.

Another item in the account is the matter of re-use. Wood is not adapted to this purpose. The loss by breakage, crushing, etc., is so great that it is rarely considered desirable to remove to a new location and to use again timber which has once been put in place in the mines; the cost of the removal is usually not justifiable from the standpoint of salvage value.

FIRE PROTECTION.

The fire risk is always with us. There are mines which by reason of the presence of gas may be more dangerous than others and in mineral mines that particular danger is not often encountered. Acts of Providence in the line of gas explosions we cannot apparently prevent. We may, however, study the modes of their occurrence and anticipate their consequences with a view to their economic control. There is sufficient danger at all times in every mine to call for the exercise of continual vigilance. It is not necessary here to discuss the great number of serious fires which have occurred particularly within coal mines, or tô endeavor to compute the loss of life and property to which they have given rise, not to mention the consequent expense in re-opening the mines and restoring them to their former condition after the fire has done its damage. A short list of such fires may be found in a paper entitled "Mine Timbering in Steel" read by your speaker before the West Virginia Coal Mining Institute at Huntington, West Virginia, in December of last year, and a significant feature in connection with this list is that not one of the fires enumerated therein was due to gas explosions, but they were all due to ordinary every-day routine conditions with which all mine owners and operators have to contend. The fire which took place on August 26th, 1908, in the mine of the Hailey-Ola Coal Company at Haileyville, Oklahoma, by which 29 miners out of 132 lost their lives, was due to the substitution of crude petroleum for lubricating oil furnished the miners for the lubrication of cars. The fire which started on November 13th, 1909, in the mine of the Chicago, Milwaukee & St. Paul Railroad at Cherry, Illinois, was due to the ignition of hay being trammed into the mine for feeding the mules. Other examples might be enumerated but they would only serve to give accumulative value to the argument and emphasize the importance of the use at recognized points of danger of those materials of construction which are fitted to reduce, if not entirely avoid, the economic wastes due to the use of wooden timbers in locations for which they are not in all respects adapted.

Why should not fireproof structures be erected in fire zones under ground as they are above ground? Shafts, pump houses, powder magazines, mine boss shanties and stables are the vitals of the mines and need protection by the use of fireproof materials of construction. Fireproof buildings underground mean safety and therewith the reduction of expense in maintenance and replacement. If there were no other reasons for the avoidance of timber in the mines the preservation of the vital parts of the mines merits most careful attention and every consideration which may be adduced for the building of fireproof constructions above ground applies with greater force to the elimination of inflammable materials from underground structures. Several legislatures have either enacted or had under consideration measures looking to the absolute fireproofing of underground mine structures, and true wisdom in the employment of materials looks with extreme disfavor upon the continuation of the use of wood in such places or else the adoption of such a form of treatment as will render the wood itself either practically fireproof or make it slow burning.

IMPROVEMENTS IN MINING METHODS.

This is not the age of brawn and brute force. Time was when men in military garb tediously drove countless thousands of weary slaves to construct by manual labor vast masonry mausoleums amidst the burning sands of Egyptian deserts, regardless of the cost in labor, groans and lives, to gratify imperial ambition; or in fair Italy forced 30,000 men in hard service with hammer, drill and creaking ox-carts for 11 long years to build a drainage tunnel that imperial Rome might have water. That age is past. Muscle has given place to brains; brawn to skill; brute force to exact science. Today is the day of the domination of mind over matter, of the amelioration of toil by the exercise of trained judgment, of the accomplishment of age-long tasks in a moment, of the subjugation of the forces of nature to the will of man to do his utmost bidding. The industrial development of the 20th century A. D. is not the work of the warrior, ruthless of men and means, but of the trained man of science who knows and then does and who authorizes the expenditure of labor and means on the basis of the relation such expenditures bear to the ultimate results.

The art of mining did not begin yesterday. It had its rise myriads of years ago in the age of main strength and awkwardness. Zillah, wife of Lamech, in the primeval epoch of

Semitic history gave birth to Tubal Cain, the forger of every cutting instrument of brass and iron before the flood of the Loess had left its mark in the Mississippi valley. Some men have rashly concluded that the mechanical arts stand, in point of time, at the head of the world's industrial development. I say to you that some miner delved in the ground and roasted and smelted the ores that Tubal Cain might have somewhat to forge. The world has grown since then and the miner of today stands head and shoulders above his prehistoric ancestor solely and only in so far as he rightly estimates and uses the materials and forces nature has placed at his disposal.

In the early days of railroad construction the roadbeds were of the roughest and the bridges were wood simply to accommodate existing loads and traffic without reference to future development, and just as the construction and maintenance of the railroads in the United States have called forth the best talents of trained men second to none in the world's history, who have rightly appreciated and used with larger and larger intelligence the materials and forces at hand, so does the history of coal and metal mining reflect great credit and honor on the men who have raised it to its present plane of development. Its record is a record of continual progress from the primitive and simple to the advanced and complex. Hand and mule methods of transportation have given place to wire haulage, to the steam locomotive, to the electric locomotive and to the employment of compressed air not only for transportation but for operation as well. Hand methods of mining have given place to machine methods. Primitive methods of pan washing for the separation of gold from placer deposits have given place to hydraulic methods of mining. The hammer and oven of Tubal Cain's miner have been succeeded by stamps and milling machines, jig separators and other equipment necessary for the extraction of the ore from the most refractory materials, whose construction, installation, operation and maintenance reflect nothing but praise on their designers. Just as Tubal Cain would be dazed and astounded were he to go into a modern machine shop, so we can picture to ourselves the astonishment with which Tubal Cain's miner would have looked upon the steam shovel.

There are reasons why this industrial development has taken place in the 20th century A. D. and not in the middle ages. They may be summed up in two words; one, the subjugation of the forces of nature; two, modern materials of construction.

STEEL THE LOGICAL SUCCESSOR OF WOOD IN MINE TIMBERING.

The building materials known to the ancients were wood, stone and brick; the first of universal distribution, the second of almost universal distribution, and the third a material which man formed in those localities where stone was not easy of access. The last two materials were adapted to solid and permanent constructions; materials of great weight and stability requiring mechanical means for their installation; suitable for foundations, walls, dams and bridges; of low tensile strength but of high resistance to compression and shearing; materials which needed special appliances and special skill for their successful employment; materials of the architect, engineer and man of abundant financial resources. Timber, on the other hand, was the material of wide distribution, with ease of access to the place of use; simple to be framed and fitted for service; for use as beams and girders to carry heavy loads over wide spans; capable of installation by manual labor alone; the ordinary material of the plain man without special skill or equipment and of limited financial resources. The ancients rightly appreciated the relative positions of these materials in the works of construction which they executed.

To these ancient materials have been added in modern days a material like stone, formed by the hand of man, called Concrete in its various forms and ramifications; hollow tile and other clay products burnt like brick in a furnace and highly refractory; copper, zinc, tin and lead rolled into sheets of exceeding thinness to take the place of wood for roof covering, etc., and above all, steel, the most perfect substitute for wood in all its uses ever known.

None of these materials is of universal application. They all have their right place and their right use but the suitability of each material to its particular service has often been overestimated and what may be called the higher materials of construction have been placed in service where their use was attended with economic waste and where other materials were better fitted to that service. Copper, for example, is an ideal material for roofing purposes; no sane man, however, would roof a tent with copper; neither would any sane man construct a building like the United States Capitol at Washington with steel. He might use steel for his interior work and in his roof framing but the structure itself as an architectural proposition is rightly constructed of enduring masonry. On the one side stand the enduring, permanent materials of low tensile strength and high resistance to compression and crushing for use in situations where mass is wanted; and on the other hand are the materials of high tensile strength, fitted to carry large loads over wide spans with the minimum of dead weight to external loading. In the use of these materials we make no mistake if we follow the lines laid down by the ancients.

Just now the material the use of which is most in question is concrete, whether reinforced or otherwise. Your speaker holds no brief against concrete just as he holds no brief against any other modern material of construction. It has its place which it is fitted perfectly to fill. As a substitute for stone or brick it has no equal outside of those situations where elements of an architectural character require something more pleasing to the eye or better fitted without deterioriation to withstand the ravages of time. Its use for foundations, for walls, for mine entrances and for tunnel linings is unquestioned. A pleasing example of the use of concrete in what may be called modern permanent construction is to be seen in Figure No. 1, portraying the entrance to the mine of the

Allport Coal Company at Barnesboro, Cambria County, Pa. As we shall see later the interior of this mine is as pleasing and modern as the exterior and the installation is in itself an illustration of the proper use of this material.

But the material which beyond question lies back of modern construction is steel. Its use is characteristic of the modern art of building, so much so that men have called this present time distinctively the "Age of Steel." It is not fitted to the service to which wise men put stone and brick but it is the ideal substitute for wood. We see this substitution on

Fig. 1. Entrance to Bituminous Coal Mine, Allport Coal Co., Barnesboro, Pa.

every hand in above ground constructions; the wooden bridge of years ago has practically disappeared, such few survivors as are still found are maintained rather for their historic interest than for their intrinsic worth; the wooden sailing ship has given place to the steam vessel of steel; the wooden 74 of Nelson's time to the fireproof steel structure of the "Dreadnought" type with its very limited but very powerful armament; the heavy freight of our modern railroads is no longer carried in the light cars for the construction of which wood was suitable but moves in modern all-steel equipment. It is an historic fact that building construction did not take on its modern aspect until steel beams and steel columns came into extensive use.

The same substitution of steel for wood in above-ground construction has found a large place in mining structures. The

Fig. 2. Wooden Head Frame, East Norrie Mine, Oliver Iron Mining Co., Ironwood, Mich.

ordinary wooden structures such as tipples, head frames, breakers, etc., are being replaced by steel with a gain not only in strength and stability but also in other lines as well. Figure No. 2 shows a wooden head frame over one of the mines of the Oliver Iron Mining Company at Ironwood, Michigan. It is strongly timbered and no doubt is adequately adapted for the service which it is called upon to perform. The low strength of the timber, however, appears in the large sizes necessary in its construction and the amount of space which the framing fills. Not very far from it stands the steel head frame shown in Figure No. 3 which is characterized by the same strength and stability as the wooden head frame

Fig. 3. Steel Head Frame, G. Pabst Iron Mine, Oliver Iron Mining Co., Ironwood, Mich.

but with several added merits; it offers less resistance to the wind, it is fireproof, it offers free ventilation, it is in every way a more ornate pleasing structure; more of an architectural triumph. A wooden head frame could be built along exactly the same lines but the difference in the two materials would be apparent to the eye at once in the grace and beauty of the one and in the awkwardness and heaviness of the other.

These are cases where the substitution of steel for wood is simply the substitution of a material of great strength and endurance for a similar material of less strength and endurance. The steel car as a structure called for no significant changes in the method of framing; the steel building is put up with columns and girders just like the wooden building; neither did the substitution of steel for wood in the case of these mine structures mean any significant change in general design. Progress in the use of steel in substitution for wood has been to simplify details of construction rather than to modify their essential character. In fact the large merit of steel for construction purposes is its simplicity. It is a material of construction, easy to obtain, like wood; convenient to fabricate and erect and has therefore commended itself up to the present time as the only material which by its flexibility and convenience of use can replace wood construction fully and satisfactorily and with minimum modifications of design.

The forms of wood which have proven themselves suitable for mine timber purposes can exactly be duplicated in steel; a set of steel gangway timbers can alternate with wooden timbers; a set of steel mine shaft frames may be alternated with wooden frames; wood may be taken out and steel put in its place; steel may be taken out and wood put in its place; there are no other materials of construction permitting such easy interchange. Wherever tensile and bending stresses are to be resisted wood and steel find their field of usefulness with this difference, that the substitution of steel for wood avoids those elements of economic waste to which timber is liable, namely, the waste in size of materials, the waste in framing, waste from decay, waste by fire, waste by reason of its low economy in point of re-use, to which may also be added as an inference from experience that the use of steel within mines means less excavation, better ventilation, less erection cost and more than all else, greater endurance.

Beyond its advantages of a technical character there is one reason which underlies the substitution of steel for wood in modern building construction. This is not the age of main strength and awkwardness. This is the age when men do things for good and sufficient reasons. Sit down if you will and count the cost, balance the account, estimate accrued interest on capital expenditure, compute reasonable deterioration of equipment; the steel car has replaced the wooden car, the steel ship the wooden ship, the steel breaker the wooden breaker, and the steel head frame the wooden head frame solely because the investment paid; because the substitution of steel for wood in spite of its higher prime cost meant increased ultimate returns which could be measured in terms of coin of the realm. This, after all, is the milk in the cocoanut. If wood be the perfect material for mine timber uses in underground construction, let the miner continue to use it, but let him do so only after he has counted the cost, weighed the advantages and disadvantages, the merits and demerits, balanced the account, computed the expenditures for maintenance and has determined that in the end the time honored material means the least ultimate expenditure; but let him remember that all experience in above ground construction indicates that wherever the installation is in any way permanent, the substitution of steel for wood pays, regardless of its first cost.

The considerations which account for the substitution of steel in above ground construction run parallel to those which theoretically explain its fitness for use below ground and are demonstrated by the history of its introduction.

1. The first recorded use of steel known to the writer in inside mine work took place about 1875 in the level at the bottom of the shaft in the Cambois Colliery in Northumberland where the height of the heading was increased to 18 feet in order to handle large pieces of machinery, boilers, etc., and where rolled girders of I-beam shape were used in the roof construction simply in order that the great loads which had

to be carried might be carried in the same way as had been possible theretofore in timber.

In like manner the first use of structural shapes in square timber sets for main headings seems to have been made in the United States in 1897 at the Stearn's Shaft of the Susquehanna Coal Company, Nanticoke, Pa., under the supervision of Mr. R. V. Norris. They were put in 540 feet below the ground surface and the conditions which caused their use were the large spans at the foot of the shaft and the great pressures under which 24" yellow pine timbers lasted only about eight months. These timbers are still in position and in excellent condition, exposed to constant contact with mine water yet without signs of failure or corrosion.

The same consideration of great strength seems also to have been the moving cause in the use of steel in the roof framing of the pump house installed by the Lehigh Valley Coal Company at Hazleton Shaft Colliery, No. 40 Slope, in the same year under the supervision of Mr. S. D. Warriner, Chief Engineer, and Mr. W. A. Lathrop, General Manager. This pump house is 51' 3" long and 24' 5" wide, built level under an inclined vein where the breaking away of the roof was naturally to be anticipated.

2. It would have been possible of course to have used timber or some other form of construction besides steel in these situations but the great strength of steel in proportion to its bulk made it preferable from all points of view in spite of the fact that previously there had been no experience in its large use. A different consideration applies to the regular mine service. The advantages in steel noted at the Nunnery Colliery, Sheffield, where 5" beams with 4" flanges and 3/8" web thickness were put in place in 1886, were their greater durability, lightness and handiness, increased space for ventilation, less deterioration in mine air and, more than anything else, the possibility of their re-use. The same consideration was early noted in the Commentry Mines, France, where steel bars used as roof supports have been in service 200

times and more. This advantage of re-use is due to the difference in the behavior of steel and wood under service conditions; steel deflects gradually under pressure and will bend greatly before breaking, and even when overstrained, can be taken out and straightened, whereas wood, in addition to the pulling apart of the fiber longitudinally, breaks also transversely. This is the reason why timber with long fibers is preferable to that with short fibers, and which makes the long leaf yellow pine the most admirable wooden mine timber material. In a permanent gangway of course the considerations of re-use are of little value. They do apply, however, where main headings are permanent and where the side headings are abandoned with the taking out of the coal or ore. It is also an item of large consideration in the use of steel for props.

3. The first proposition for the substitution of structural steel shapes in the place of wood in mine timbering operations in the United States seems to have been made by the Carnegie Steel Company in 1894, on the basis of the ultimate economy in expenditure which results from low maintenance charges and infrequent renewal. All the experience at hand indicates that this consideration is after all the most important, as it is indeed the consideration which accounts for the large use of steel in above ground constructions. A record of the development of the use of steel in coal mines along this line will be found in the paper on "Mine Timbering in Steel" mentioned above. Lucius W. Meyer in his "Mining Methods in Europe" also speaks of the general prevalence of the use of steel in England and discusses certain forms of mine timber sets which have had extensive use in Germany. It is significant that these sets are not of large size for special uses but the ordinary forms which are needed in the extension of the smaller headings.

4. It is also noteworthy that the proper form of material has a large influence in its use. Progress in England dates from 1885 when the Darlington Iron & Steel Company

began to manufacture sections especially adapted for roof beams in place of wood in pit workings and for steel props in supporting the roof. They placed on the market steel beams 5" deep with 4" flange and a 3/8" web which came into immediate preference to wood or cast iron on account of their resistance to bending. The advantage of this form of section, which we call in the United States an "H" section, consists in its large radius of gyration and its especial fitness for use in resistance to compression. So also in the United States a fresh impetus to the use of steel in underground timber construction was given by the rolling of H-sections by the Carnegie Steel Company in July, 1907. These sections are made in four sizes—4", 5", 6" and 8" in depth—and are ample to sustain safely the ordinary loads to support which timber legs can be used in the regular three-piece gangway set.

TYPES OF CONSTRUCTION IN LEVEL HEADINGS.

The character of the installations which have been made in the mines of the United States varies—in fact, there is no typical form of construction in wood within the mines which has not satisfactorily been replaced by steel. The H. C. Frick Coke Company, for example, has timbered with steel 23 pump houses, 5 stables, 14 engine, motor and locomotive rooms, 10 shaft bottoms, 1 main butt haulage and 3 foreman offices; five of these structures are over 300 feet in length, each.

1. Roof Supports. Steel was first used for roof supports in the form of rails, to be followed by rectangular bars supported directly on the coal or on the rock, and in the southeastern Ohio mines of the Youghiogheny & Ohio Coal Company and Roby Coal Company can be found quite extensive installations of gangways maintained by the use of I-beams laid directly on the coal. Where the coal is good and solid, this simplest form of construction finds ready use. A more common practice in the permanent roadways of English mines is to lay the beams on long walls built from waste rock or brick. The use of masonry in this manner, whether of concrete, stone or brick, while quite common in Europe, does not

seem to be very extensive in the United States; at the same time, examples of the use of steel on masonry walls may be found in the collieries of the Delaware & Hudson Company at Scranton, the mines of the H. C. Frick Coke Company, etc.

In some states the mine inspectors object to the supporting of timbers directly on solid coal and great care should be exercised not to permit any excessive loads to come thereon. This has been prevented in some instances by the use of sprags

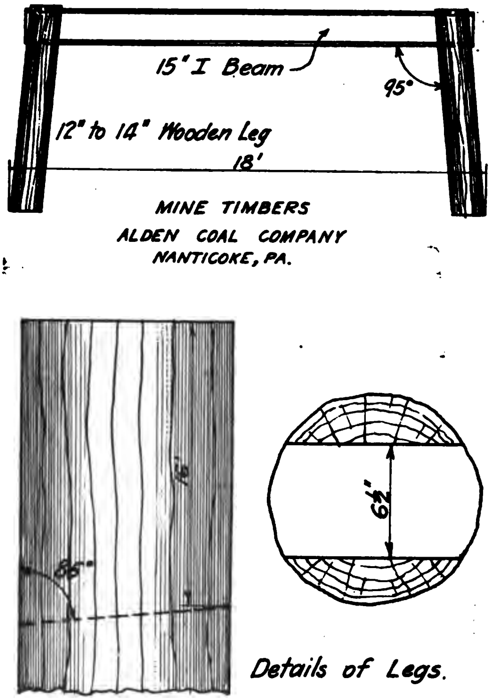


Fig. 4. Combination Mine Timbers.

or short timber props to carry the loads to a secure footing. An excellent way to combine the use of steel with wood is to use steel for the collar of a gangway set and wood for the legs, the steel being relatively better adapted to resist bending stresses under transverse loads while the compressive strength of wood is very much greater than its resistance to bending. This has been done, among other places, in the Adrian Mines of the Rochester and Pittsburg Coal & Iron Company at Punxsutawney, Pa., where 4″ H-sections have been used to replace wooden timber collars 8″ square. These H-sections are spaced 4 to 5 feet centers and are supported at their ends on round timber posts, making a very solid and substantial construction. The additional 4″ of head room gained by their use was also a factor in their favor. In the instance above mentioned the steel mine collars rest directly on the top of the wooden posts. A more satisfactory form of con-

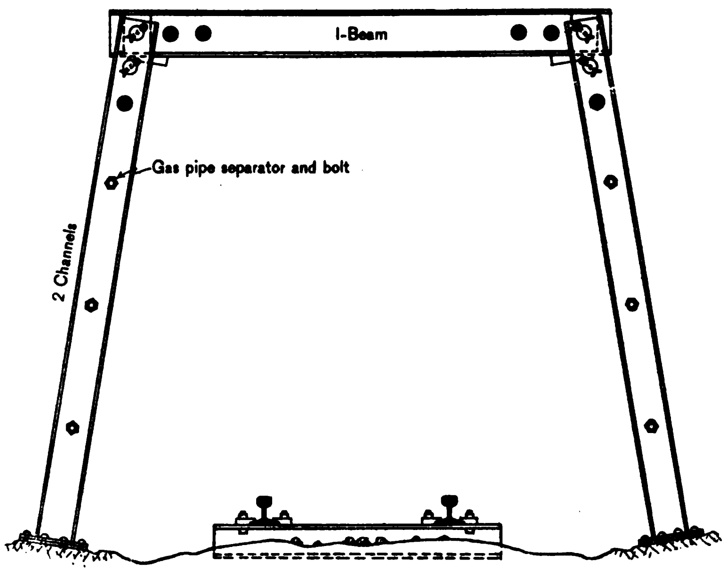


Fig. 5. Steel Gangway Support, Style B

struction is shown in Figure 4 which represents combination timber sets used by the Alden Coal Company at Nanticoke, Pa., where a 15″ I-beam collar is placed squarely across an 18-foot gangway and is fitted into a wooden leg at each end. An item of importance in this connection is to so proportion the size of the wooden posts to the steel collar as to prevent crushing of the wood immediately under the steel, the crushing value of wood being low. This point has also been noticed by Meyer who says (page 157) that this particular form of drift set is often seen in England, with this difference that in England railroad iron is more frequently, though less economically, employed than I-beams, and the only objection to their use which he mentions is that of the splitting of the top of the post.

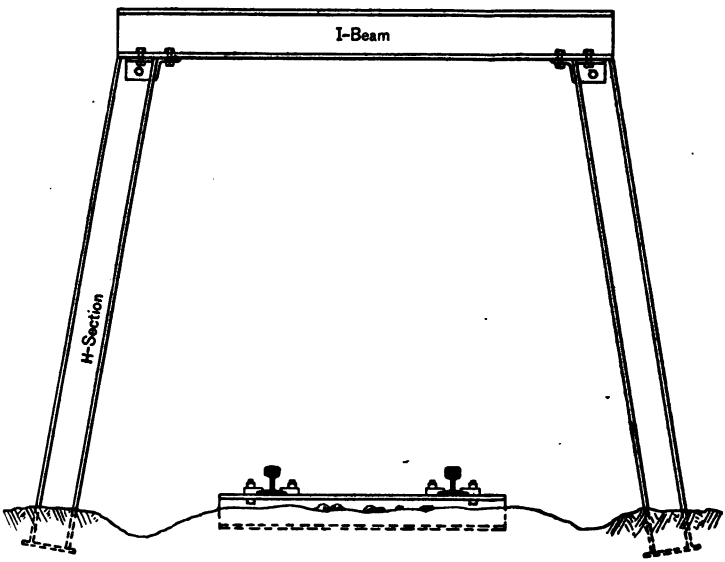
2. Gangway Supports. The all steel three-piece gangway support represents, beyond question, the best and most economical form where legs are required, as the use of steel legs prevents the splitting and crushing of the wood already referred to and also permits a much greater economy in material than is possible in the combination sets. This is largely the reason why the gangway sets in Germany have followed this latter line of development rather than English practice, a common form used in Germany being shown in Meyer's book and consisting of I-beam legs and collar resting upon and connected together by T-irons extending longtitudinally of the drift. In the design of a steel gangway support set two lines of development have been followed in the United States —the one based on the idea that adjustability is necessary, and the other on the idea that all essential requirements have been met when steel replaces exactly the wooden construction, there being no adjustability in the ordinary three-piece gangway set.

It is a matter of history that the first structural steel gangway supports used in this country were adjustable. The most recent modification of the original design is shown in Fig. 5, Steel Gangway Support Style B, in which the collar is composed of an I-beam which frames at each end between two channels separated by gas pipe separators. Two pins are used at the top of the legs and steel wedges are driven under the collar to distribute the weight on both of them; additional holes serve to take up differences in width and height. The channels rest upon steel plates on which bars are riveted to hold them firmly in position, whereas the original design employed heavy castings at this point. The cost of this type of construction is comparatively high but it may be adapted to almost any requirement of strength and is to be recommended where adjustability is considered absolutely necessary. Large stretches of steel timbered gangway in the Anthracite region are timbered after this design, originally prepared by Mr. R. V. Norris, Consulting Engineer, Susquehanna Coal Company. Examples are to be found in the mines of the Lytle Coal Company, Minersville, Pa., Lykens Valley Coal Company, Williamstown, Pa., etc.; and in the Bituminous fields at Eureka Mine No. 36, Berwind-White Coal Mining Company, Windber, Pa. Fig. 6 shows a single stretch of 1,500 feet in-

Fig. 6. Steel Framed Gangway, Style A., Summit Branch Mining Co., Williamstown, Pa.

stalled by the Summit Branch Mining Company at its Williamstown, Pa., Colliery. The lagging in this instance is of round timber poles. As an illustration of the simplicity of this construction it may be said that the fabrication of the sets for Eureka Mine No. 36 was done by the Berwind-White Coal Mining Company in their own shops.

The writer is one of those who believes that economical use and the elimination of refinement go hand in hand. He sees no reason whatever why a steel timber set should be any more adjustable than one of wood and believes the ideal form for simplicity and economical construction is to be found in Steel Gangway Support Style F, shown in Fig. 7, which consists of an I-beam or H-section collar supported on two H-section legs with lug angles at the top to prevent side motion and absolutely plain plates for bearings. The lug angles at the flange of the H-section may be replaced by bars as has been considered preferable, among others, by the Lehigh & Wilkes-Barre Coal Company in their Maxwell Colliery. In



Steel Gangway Support, Style F

Fig. 7.

this form the square timber set is the exact equivalent of the three-piece wooden set in common use. The first sets of this design used in the United States were installed in October, 1907, in the pump house of the Midvalley Coal Company at Wilburton, Pa., and the steady demand for them indicates their perfect adaptation to the usual purpose of gangway timbering. Examples of their use are now to be found in most of the larger mines in the Anthracite and eastern Bituminous coal fields, installations having been made during 1909 by nineteen different coal companies. An excellent installation is shown in Fig. 8 which represents the interior of the bituminous coal mine of the Allport Coal Company at Barnesboro, the exterior of which was shown in Fig. 1 as an example of recent improvements in outside structures. These timber sets weighed about 372 pounds each, were lagged in place by 2" plank and concreted up to car height. The sets were handled by three men without difficulty and with dis-

Fig. 8. Steel Gangway Supports, Style F, Allport Coal Co., Barnesboro, Pa.

patch; the writer saw in this installation two complete sets erected in 15 minutes by the watch.

3. Pump Houses. The earliest example of a steel framed pump house is probably that of the Lehigh Valley Coal Company at Hazleton, Pa., built in 1897, where 12" 35lb I-beams were used for framing resting on and joined by special castings and lagged with steel rails backed with concrete. This pump house shelters a Corliss cross compound surface condensing pumping engine of 3,500 gallons capacity per minute under a steam pressure of 100 pounds per square inch

and 550 feet vertical head. This is one of the few high duty pumping plants which have been installed in the coal mines and showed on test 5,141,247 gallons of water in 24 hours and a duty of 103,805,456 foot pounds per thousand pounds of steam.

The simplification in detail which has been attendant upon the increased use of steel in mine timbering and the progress which has been made in twelve years in machinery and equipment can be shown by a comparison of this pump house shown in Fig. 9 with that shown in Fig. 10 which illustrates the con-

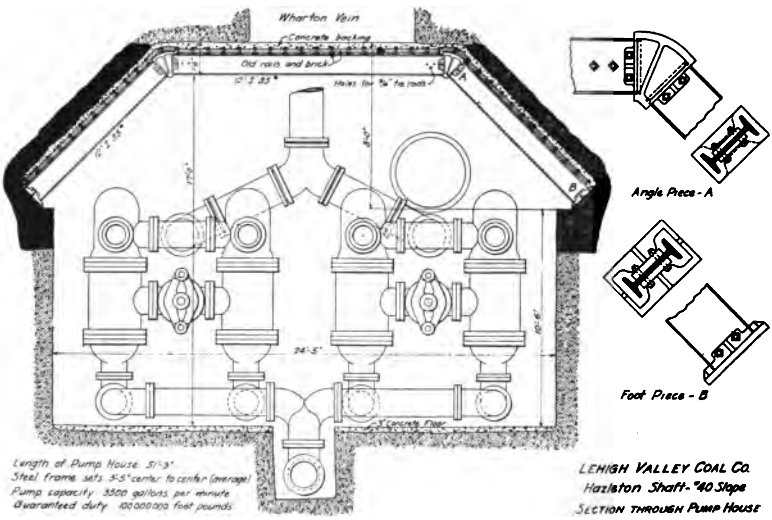


Fig. 9, Concrete Lagged, Steel Framed Pump House, Lehigh Valley Coal Co., Hazelton, Pa.; built in 1897.

struction of a steel lagged, steel framed pump house built by the Pennsylvania Coal & Coke Company at their No. 5 Mine, Ehrenfeld, Pa. This pump house shelters two 7x9 Aldrich plunger pumps, capacity 500 gallons each per minute, driven against a 530 foot head at 50 revolutions per minute by two 90 H. P. Westinghouse motors. The surface at bore hole is 1,613 feet above sea level; suction end of pump 1,103 feet above sea level; bottom of sump 1,083 feet above sea level; location of pump house 3,300 feet from entrance of mine. The house is 30 feet long, 22 feet wide and 15 feet high in the clear of roof supports. The framing is built of eleven sets of Style F Mine Timbers with 6" H-section legs and 6" H-section collars. The collar is supported in the middle by a 20" I-beam which carries a trolley for handling all machinery and rests on three 6" 23.8lb H-section posts at center and ends. The legs rest on concrete bases and the whole structure is lagged complete by 3/8" steel plates held in position by 5/8" bolts. There was no wood used in the construction of any portion of the pump house and the structure is, therefore, absolutely fireproof.

4. Lagging. Many kinds of lagging have been used with gangway supports of steel; in some cases short round

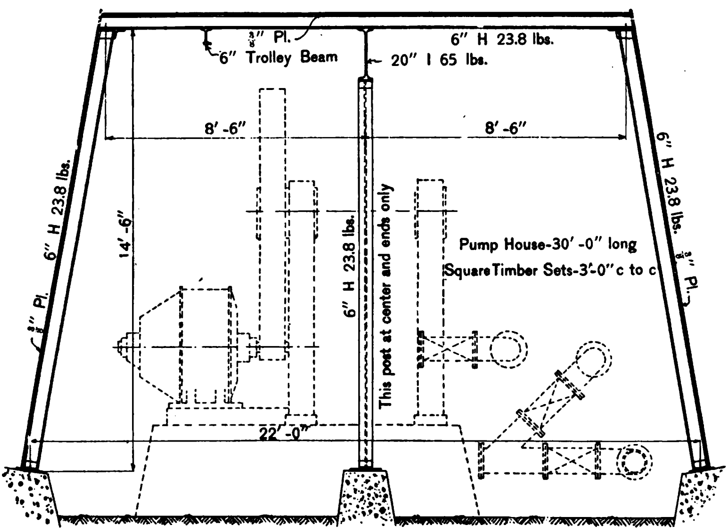


Fig. 10. Steel Lagged, Steel Framed Pump House, Pennsylvania Coal and Coke Co. Ehrenfeld, Pa.; built in 1909.

poles; in other cases plank; in still other cases old rails. The pump house of the Midvalley Coal Company at Wilburton, Pa., in which were placed the very first H-section rolled by the United States, was lagged with old rails. A most excellent installation would consist of thin concrete slabs made on wire netting and placed in between the flanges of the beam so as to permit easy removal if broken. The use of 3/8" boiler plate as employed in No. 5 Mine of the Pennsylvania Coal & Coke Company at Ehrenfeld, Pa., has considerable English practice to commend it. So far back as 1892 Mr. J. Johnson described his experience with such lagging in the transactions of the Manchester Geological Society. Six years before he had timbered 900 feet of main road with iron props and steel girders three feet apart, lagged with ¾" boiler plate, and at that time had 4,200 feet of main road so timbered. The legs were made of 5" beams with 3" flanges 6 feet long, and the collars of 5" beams with 4" flanges 10 feet long. The first cost was three times that of wood but the first installation had then outlasted six sets of wood and was as good as new—not a girder had been replaced. In 1888, or earlier, a system of iron rail arch supports combined with corrugated iron lining, for use in timbering gangways, was patented by Meyer and his patent was in all likelihood based on actual use, at least to some extent. In 1897 it is recorded that corrugated sheeting had been in use for sometime in the Griff Colliery near Nuneaton, England; black corrugated arch sheets were employed of No. 15 gauge 5½ feet long by 2¾ feet wide with a spring in the arch of 15"; each sheet had seven corrugations and was supported on the side, a few bricks being used if necessary. In situations where moisture conditions do not raise any presumption of early corrosion corrugated iron has much to commend it provided penny wise and pound foolish economy does not unduly cut down its thickness.

5. Props. So far as the writer is aware there has been no use of steel for isolated mine props in the United States. Abroad the use of metallic props has extended along two lines. In England the recorded instances are almost all of the use of a single piece stick made from a rolled structural shape forged to an even bearing or wedged at each end by timber. Cast iron props were in use in the Midland District in 1885 but about that time the 5x4" beam with ⅜" web came into use and a method for removing and resetting them was devised by M. Baily about 1888. Steel props were also used by H,

W. Hughes in the Midland District in 1890. They were made by slitting out the web of the 5″ beam with 4″ flange some 3″ from each end and bending the flanges over in a forge to produce a smooth bearing surface. In 1905 props of this kind were used in the Sandwell Park Colliery, West Brownwich, England, in lengths up to about 7 feet, and at the Bargoed Colliery of the Powell-Duffryn Company the props were made of the same size beams after the Hughes method. In Germany the tubular collapsible prop seems to have come into larger favor. They made their first appearance about 1902, as at that time the Sommer patent props made of Mannesman weldless steel tubes had been tried with success in the Ostrau-Karwin Coal Field. They were also tried with very satisfactory results at the Julius Mine in the Northwest Bohemian Brown Coal Field. In 1904 iron props made of Mannesman tubes had proved more economical than ordinary timber at the Nordestern Colliery at Wattenscheid. These tubes were in two parts, the top section fitting into the bottom, and were held in place by set screws and other devices, giving a strength up to 16 tons direct compression. The forms of mechanical props as used in German mines are described in the Engineering and Mining Journal for August 28th, 1909.

Inasmuch as the forms of wooden props are not adjustable and the seams vary but little in thickness, it does not seem any more necessary to provide very much variation in the length of props than it is really desirable to provide adjustability in the three-piece timber set. The English use of H-sections with plank caps or thin steel plates has much to recommend it for mine prop work, but the slitting of the webs and bending over of the flanges so as to form a bearing for the steel suffers from excessive manufacturing cost and appears a needless refinement, while the adjustability attained by the German devices seems also too expensive and unnecessary for much consideration. The best and simplest form in steel which can be devised under present mining and manufacturing conditions is an H-section cut to length and resting on a plain plate on the floor and having a similar cap wedged against the roof by wooden wedges, or the H-section may bear against wooden blocks at both ends.

CHARACTER OF STRESSES IN MINE TIMBERING.

The prevention of economic waste in mine timbering demands economy of material, space and time; of material that each piece may do work up to its full capacity—no more, no less; of space for the prevention of useless and profitless excavation; of time in order that the greatest possible endurance

Fig. 11. Timber Broken by Squeeze, Anthracite Coal Mine, Scranton, Pa.

may be gotten from the timber and labor avoided in repairs and renewals. It requires, therefore, that practice in mine timbering be based on correct principles of engineering design which, in turn, require accurate information as to the loads to be carried and the stresses induced thereby. This accurate information is not easy to obtain. There are no well defined rules by which, for example, the strength of square mine timber sets or props or the minimum sizes of shaft sets may be calculated. Wooden mine timbers are installed largely by intuition on the basis of experience in their actual use either in the particular mine in which they are used or elsewhere. Even in the case of vertical shafts through undisturbed horizontal strata the pressures to be sustained are dependent largely upon local conditions met with in sinking; one shaft may require very little material owing to its dryness, whereas in the next shaft the presence of abundant water immediately changes the aspect of the problem. Even in horizontal headings through good material where the timbering may by experiment be reduced to minimum sizes, the presence of a fault may at once change conditions.

So far as the proper designing of sections is concerned, the conditions of a technical character are only two; first, as regards the magnitude of stresses, and second, as regards the proper form of material to be used to meet those stresses. As already outlined, the magnitude of stresses to be met is largely problematical and irreducible to exact science so as to permit of mathematical computation. The character of these stresses, and in consequence the proper form of section, can readily be understood from a study of the behavior of material in underground construction under loading.

Here the axiom applies that "nature abhors a vacuum." It has been demonstrated by science and is observable in countries subject to earthquake that the most solid constituents of our globe are, to a large degree, mobile; that is to say, that as atmospheric pressure causes the immediate closure of any vacuum made by electric action or otherwise, so the tendency of the most solid strata of the earth is to close any opening made therein. This tendency exhibits itself in the Anthracite region, particularly where the measures are inclined, in the well known squeezes whereby the strata slide one upon the other, with the result of closing up the workings. Where the squeeze passes over a gangway timbered in the usual manner, the effect of this action is seen in the crushing in of the collar by downward deflection and the breaking off of the legs by bending inward from each side toward the center line of the heading. The effect of this bending on single pieces is shown in Fig. 11 illustrating timber broken by squeeze in an anthracite coal mine at Scranton, Pa. It will be noted that some of the props are still standing uninjured while others, probably weaker or damaged by decay, have failed by combined bending and compression at about one-third of their length.

The same thing occurs in an iron mine under the caving system, the tendency being always for the legs to break or shear off at about one-third their height, the pieces always falling toward the center of the excavation, while the collars

Fig. 12. Broken Timber, Chapin Iron Mine, Oliver Iron Mining Co., Iron Mountain, Mich.

fail either by breaking at the middle or by shearing at the ends.

Fig. 12 shows the upper half of some broken gangway sets in the Chapin Iron Mine at Iron Mountain, Mich. In this case the legs have split at their top by crushing and the ends of the collars are similarily broken. The condition here is that due to the bodily movement of the timber under superimposed moving load caused by mining under the caving system.

A characteristic failure of gangway timber is shown in Fig. 13 illustrating broken material in the gangway of the G.

Pabst Iron Mine, Ironwood, Mich. The pressure in this case came from the right where the timbers have splintered and broken, whereas on the left of the heading they remain practically uninjured.

Fig. 14 shows broken timber in a room of the Pioneer Iron Mine at Ely, Minn., where under the caving system the pressure has come on the timber from both sides, in each case producing a similar result; namely, the failure of the timber by deflection towards the opening.

These examples are all indications of the fact that failure in such instances is to be expected by bending in addition to

Fig. 13. Broken Timber in Gangway, G. Pabst Iron Mine, Ironwood, Mich.

direct compression. However, where the headings pass through horizontal strata, failure may be expected to take place in the legs by direct compression only, and in the collars by transverse bending only, provided that the material in the collars is of sufficient crushing strength to prevent failure at the ends. The condition is not very much different where we have to do with swelling ground, in which case instead of the sides coming in, the bottom comes up or the top comes down, thus again throwing a bending stress into the legs of a gangway support. In this case, however, it is probable that the failure will be towards the outside of the heading rather than towards the center.

The stresses to which the framing of a shaft may be subjected vary greatly with the character of the material through which the shaft penetrates. They may also vary with the verticality of the shaft, the members of an inclined shaft being subject to different stresses from the members of a vertical shaft. The same technical considerations apply in general regardless of whether the shaft is vertical or whether it is horizontal, the buntons, wall plates, etc., being almost always placed normal to the axis of the excavation whether vertical, inclined or horizontal, and what transpires in a horizontal

Fig. 14. Broken Timber in Room, Pioneer Iron Mine, Oliver Iron Mining Co., Ely, Minn.

shaft finds its parallel in a vertical or inclined shaft.

As an interesting item in this connection and as a direct illustration of the point we are making it may be noted as a historic fact that cast iron tubbing for mine shafts came into use in England more than 50 years ago. W. W. Smyth in his "Coal and Coal Mining," fifth edition, 1880, page 118, refers to the Sheiroaks Colliery owned by the Duke of Newcastle and completed in 1858 under the supervision of C. Tylden Wright. The shaft was 1,545 feet deep, 12 feet in diameter and lined with cast iron tubbing for 510 feet. In 1864 James Henry Greathead became a pupil of P. W. Barlow and paid his attention, as is well known, to the construction of underground railroads. Barlow was the author of a scheme to construct such railroads in cast iron tubes built with the aid of the shield method of tunneling. It is more than likely that Barlow's idea is the application to horizontal passages of the method of construction which had come into use in the lining of mine shafts, and it may, therefore, be stated as a historic fact that the Pennsylvania Tunnels into New York City, justly considered one of the engineering triumphs of our day, are but the development of mining methods as applied to shaft lining and a demonstration of our position that methods of constructions which have proved eminently successful in level headings can be used with certainty and success in vertical shafts as well.

The shearing value of steel is large in proportion to its tensile and compressive strength and need not, therefore, be considered in the selection of the proper form for mine timbers. In a level heading through horizontal strata all that is necessary to do in the design of a three-piece timber set is to proportion the legs to the collar so that the compressive strength of the legs will be identical with the half load thereon. Where the dip of the strata is great or where the ground is swelling, legs and collars may be called upon to take both bending and compressive stresses at the same time and allowance must be made in the design for this joint action. In a vertical mine shaft through solid ground the loads which need to be borne will not be much greater than the weight of the lining itself and stiffness and strength will only be required for the proper alignment of the cage guides, etc. There is this difference, however, between a shaft and a level heading, and that is, that in a shaft the pressure may be expected from all four sides and not from one side only. The wall plates in a shaft which passes through horizontal strata will, therefore, be subject to bending stresses combined with direct compression, the load inducing the bending stress being applied transversely and the load inducing direct compression being applied at the end from the next adjacent wall plate. Under this condition the buntons or compartment separators will take direct compression only except of course such small bending stresses as may be induced by their own weight and the weight of the guides. Where, however, a horizontal shaft passes through inclined strata or an inclined shaft passes through horizontal or inclined strata, the effect on the members will be different, the buntons or compartment separators having to take a bending stress of large moment in addition to direct compression, the wall plates not being sensibly affected.

Under any of these conditions the H-section shows its advantage for framing as compared with other forms of steel just as rectangular timber has proved itself more advantageous than other forms of wood. The H-section has the advantage for wall plates of a large bearing surface as compared with beams or channels of the same depth, and for buntons and compartment separators the advantage of a large compressive strength combined with a comparatively high moment of resistance against bending. Wherever, therefore, these elements of strength and stiffness are required, the H-section is to be recommended as the section which possesses the greatest strength for the least weight and their use for mine shafts has already given that same satisfaction which has been so conclusively demonstrated in level headings.

KINDS OF SHAFTS.

The circular shaft is doubtless the easiest form of construction and the early shafts were probably nothing more than deep wells put down in the same manner as wells are usually dug and lined. The hoisting apparatus consisted of a windlass, ropes and buckets, and the earliest recorded description of mining methods illustrated this type of construction. The same kind of shafts with round buckets of large size for hoisting men and materials are to be found, for example, in the zinc mining districts of this country.

The circular shaft lined with brick or cast iron is extremely common in England and on the Continent. Meyer in discussing English practice remarks that the rectangular shaft is rather common in Cumberland, indicating that elsewhere its use is rather uncommon, and it is noteworthy that of the 14 shafts described in his book on "Mining Methods in Europe" all are circular with the exception of one, and that one is elliptical. It is also worthy of note that of 150 shafts listed by J. Riemer in his book entitled "Shaft Sinking Under Difficult Conditions" all but 5 are circular. Meyer also notes that there is a circular shaft in a Grundy County coal mine near Coal City 60 miles west of Chicago. Outside of this the writer does not recall but one other instance of a circular shaft which has come under his own observation, and certainly the common form in the United States is the rectangular.

The advantages of the circular shaft as compared with the rectangular are stated by R. A. S. Redmayne in Vol. 2 of his work on "Modern Practice in Mining" to be—

(a) The decreased cost of sinking due to the elimination of corners.

(b) The smaller cost in lining, a rectangular shaft lined with timber costing £2 5s per foot, whereas a circular shaft lined with brick at 20 shillings per thousand would cost £1 4s 2d per foot.

(c) The greater difficulty of shutting off water in the square shaft.

(d) The greater difficulty of placing a rectangular shaft in the most suitable situation with regard to surface and underground arrangements, position of railway sidings, etc., it being desirable that the greatest length of a rectangular shaft should be across the cleat of the stone so that the long side may be in the position most easily supported.

(e) The increased danger and increased expense in a rectangular shaft when it passes through a fault.

(f) The greater durability of cast iron and brick usually employed in lining a circular shaft as compared with the timber with which the rectangular shaft is lined.

These considerations in the ultimate analysis are due largely to differences in mining conditions and the practice in building shafts in England and on the Continent is different from that which obtains in America largely by reason of the different geological characteristics of the material through which the shafts are sunk and the materials which are used in their construction. In certain parts of England, for example, and in certain mines on the Continent the upper strata are of recent geological origin; the shafts are sunk in the valley while the seams of coal or ore mined outcrop on the hills or at the surface, sometimes many miles away. The result of this configuration of the soil is to permit enormous masses of water to percolate into and form reservoirs in the strata lying above the coal or ore. As the shafts are sunk these strata of course have to be penetrated, causing difficulties in the way of pumping and keeping out the water. By reason of this difference also the pressures on the shaft lining increase approximately in the ratio of the hydrostatic head. In the United States, however, the coal mines are either not of any great depth, or where they are, they almost always pass through strata of Carboniferous time which are approximately horizontal, very hard, free from faults and relatively free from water. In the iron mining regions the ore occurs in troughs of slight extent with the strata deeply fissured, folded and faulted, consequently the shaft is sunk through the outer crust of the earth which may contain considerable quantities of water with loose material, such as sand, gravel, shales, etc., but after rock is reached the extremely hard character of the material eliminates difficulties of the character met with in England. In England and on the Continent also suitable brick for lining shafts is not very much more expensive than wood, if at all, and what little difference there is in expense of first cost is overweighed by the considerations of durability and maintenance which, as are well known, are paramount in English and Continental construction. For these reasons the English and Continental mines are usually constructed through water bearing strata with circular shafts which offer a high degree of resistance through arch action to the pressure from the surrounding material. These shafts

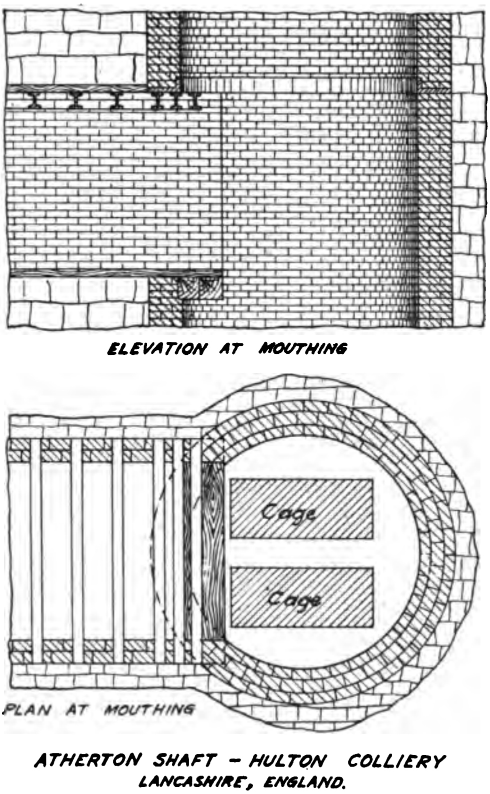


Fig. 15. Brick Lined Shaft, Lancashire, England.

when shallow and through firm strata are usually constructed of brick, and Fig. 15 shows what may be considered common practice in English shaft and heading construction and indicates the solid and fireproof construction of the shaft itself with the strength and stability of the gangway supports. The mines owned by the Hulton Colliery Company in the Lancashire Coal Field have a total output of about 500,000 tons per annum, the bulk of which is raised from two shafts known as Atherton No. 3 and Atherton No. 4, which were sunk in 1900 and are each 24 feet in diameter in the clear. The shafts are lined with brick and the mouthings (gangway approaches to shafts) for the upper seams and at the bottom of both shafts are formed on a method now much approved in this coal field. Strong steel beams are set upon side walls of brick; two beams 12″ wide by 7″ deep are placed immediately under the last bricking ring of the shaft and are repeated at intervals of 12″, the single beams at more frequent intervals. These beams are covered to form lagging with 2″ pine plank or ⅜″ boiler plate. Side walls are good brick work three to four feet wide. Where the floor is bad, the thickness at the bottom may increase to 5 feet and taper to 2 feet or 2 feet 6 inches at the top.

Where the shafts pass through strata such as the Magnesian limestone in the north of England, the Permian sandstone of the Central Countries and the Chalk and Green sand in the north of France and Westphalia, which carry large quantities of water, the main dependance is on cast iron tubbing which is built up in segmental framing rings piled upon each other throughout the entire depth of the water bearing strata, this kind of lining being also peculiarly adapted to the circular form. The thickness of this lining is usually figured to resist hydrostatic pressure, the minimum thickness being about ¾″ and running to 4-¾″, which is generally recognized as the maximum thickness which can safely be manufactured and readily handled. A new method of lining has been introduced in France which uses an iron ring ¾″ thick lined inside with reinforced concrete of a thickness and strength to carry the pressure, the iron ring serving merely to protect the concrete from the water. In cases where iron rings 4-¾″ thick were formerly in use the saving in metal by the new system was about 20 tons per meter of shaft, the latter being six meters in diameter, the iron tubbing being the same thickness for all pressures. In the method of sinking shafts through water bearing strata adopted by Kind and Chaudron in Belgium and Germany shafts have likewise been lined with wrought iron plate tubes, and as rolled material has come into larger use, the cast iron tubbing has been more and more replaced by steel plates and shapes. So far back as 1894, for example, at the Grimsby Iron Ore Mine in the Siegen District, Prussia, the shaft from the sixth to the seventh level was built of channels. At the Bockswiese Mine, in the Harz Mountains, iron lining of I-beams was experimentally adopted in place of masonry. The rings were 2′ 6″ apart lagged with tees, the intermediate spaces being filled with stone, at a cost of 6% less than the ordinary masonry methods of construction.

If, however, the circular shaft is built large enough to carry the rectangular cages which are in almost universal use, there will always be an excess useless area requiring an excess of excavation as compared with the rectangular form, which, in turn, is best adapted for framing in wood or steel and which offers the largest useful area for a minimum amount of excavation. On the other hand, for the same area the perimeter of a circular shaft is less than that of a rectangular shaft. The useless area in a circular shaft may run from 25% to 45% and means that much additional expense in excavation and maintenance which must be offset by cheapness of lining material in order to make it economical as compared with rectangular construction. The rectangular form of shaft conforms to the cages and skips which are used in hoisting men and materials and represents, therefore, the minimum of excavation, and if properly divided by compartment separators of sufficient stiffness, offers no special difficulties from a technical standpoint. It is the form best adapted for framing in wood, and if framed in wood, steel may be substituted therefor with perfection, these materials being interchangeable and the variations in details insignificant. The cheapness of timber as a lining material has, therefore, made it more satisfactory from the standpoint of American mining practice and the chief advantages of the circular shaft in England and on the Continent do not, therefore, have very much force under American conditions. The rectangular shaft may, therefore, be considered as the typical and best form of construction. The circular shaft has an advantage over a rectangular one in that it offers less rubbing surface and hence less friction to the air currents and provides better ventilation. The mining laws, however, almost always require separate air shafts and this consideration also is of little force.

The elliptical shaft is an endeavor to combine some of the advantages of the circular shaft and the rectangular; namely, strength and economy of space, but has not met with favor in England owing to the difficulty of keeping a deep shaft of that shape plumb and the obstacles presented to effective walling or tubbing. In Redmayne's discussion of this subject, however, the use of concrete seems to have been overlooked. The concrete lined shaft is almost always elliptical in form and concrete seems to be the material best adapted in the construction of elliptical shafts, though it is possible to use brick. The difficulty in the use of cast iron segmental lining is due to the fact that special sections would be required, whereas in the circular shaft the sections may be made all alike and interchangeable. In the elliptical shaft there is some elimination of useless space. It is safe to say that the elliptical shaft comes between the circular and the rectangular so far as availability of space is concerned. The elliptical shaft also takes advantage of arch action in the material itself so that the concrete may be made of less thickness than if rectangular. The concrete lined shafts built in the United States have usually been sunk by the caisson method, the lining being built upon a steel cutting edge from the ground upwards and sunk into position by its own weight, whereas with the cast iron or wooden lined shaft the extension of a shaft may proceed by building from the lower end downwards or by extensions downward in short sections successively built up on wooden or steel bearers. The caisson method of sinking is limited to about 120 feet. It is satisfactory through soft materials but not through hard, and below the ground rock level friction on the sides, the difficulties of excavation, etc., increase enormously.

EXAMPLES OF STEEL SHAFT CONSTRUCTION.

The various uses of steel in connection with the construction of mine shafts may be advantageously illustrated by a few representative examples, the discussion of which will serve to bring out also its advantage in this form of construction. As already mentioned, the cast iron segmental lining has been employed in the construction of the Pennsylvania Railroad Tunnels into New York City. It is to be found also in the tunnels of the Hudson & Manhattan Railroad, of the Grand Trunk Railroad under the St. Clair River, etc., etc. It is not of universal use in subsequeous tunnel construction, as rolled steel tubes have likewise been employed for the same purpose, though the segmental form of construction has many advantages to recommend it both for horizontal and vertical headings. The writer will not say that there are no cast iron lined mine shafts in the United States, but only that none such have come under his observation. If there are any, he will appreciate any information as to their whereabouts, dimensions, depths, etc.

A method of lining based on the same idea in steel is to be found at the Mt. Lookout Colliery of the Temple Iron Company. Here the original timbered shaft was carried down to rock through quicksand, and when it had decayed, it became necessary to put in some material which could be placed without disturbing the original structure and without cutting down the working space in the compartments for coal hoists, water hoists, etc. Fig. 16 shows the details of this construction in which 12" channels were used back to back separated by anchor plates to catch in the wood of the original lining and double 6" channels to take the place of the 10x12" buntons originally separating the compartments. The construction was very simple and could be made more so by the use of H-section which are better adapted to resist compressive stresses developed by the earth pressure than the channels, and of less weight as well.

The use of this form of construction in sinking new shafts would avoid the excavation of from 3 to 4 feet additional space around the shaft opening and very materially lessen the original cost of the construction. The lining, after the same fashion, could be constructed for a rectangular shaft by the use of steel beams spaced about 4 feet centers laid with webs

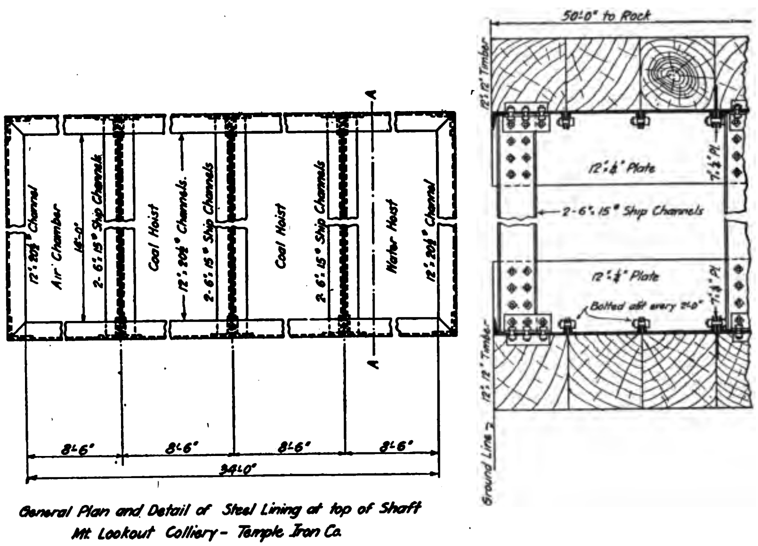


Fig. 16. Steel Lined Shaft.

horizontal, suspended one set from the other with heavy rods or angles and filled in between with concrete, in which case it would be necessary only to provide forms for the inner faces of the shaft and to have the beams punched with holes sufficiently large for pouring grout through them to fill up the small spaces between the flanges of the beam and the web. In this manner the strength of steel for shaft timbers can very readily be utilized in connection with the desirability of concrete as a permanent lining material.

The very first use of Friestedt Interlocking Channel Bar Piling on a commercial scale was in sinking the shaft of the Johnson City & Big Muddy Coal & Mining Company, Johnson City, Ill., through quicksand 70 feet below the surface. It has also been used by the Robert Gage Coal Company at Bay City, Mich., in a similar construction after endeavors had been made to sink three times without success, and at an estimated saving of $35,000.00 if the piling had been used at the start. It has also been used by the Weaver Coal & Coke Company, at Du Quoin, Ill., Big Muddy Coal & Iron Company, at Murphysboro, Ill., etc., etc. These installations were not all permanent. A noteworthy example of its use as a permanent lining of a rectangular shaft was at New Biggen, England, where piles of mild steel 80 feet long built up in lengths of 20 and 30 feet spliced so as to break joints were driven by an ordinary pile driver through 18 feet of clay, 60 feet of running sand and 2 feet into sandstone, with entire satisfaction and complete success. This is the greatest depth to which interlocking steel sheet piling has ever been driven and exposed to view by excavation. The piling can be used either in rectangular or circular shafts, what is known as United States Steel Sheet Piling being peculiarly adapted to circular construction. The chief difficulty in respect to the use of steel sheet piling, as also to any kind of piling, is the preservation of its verticality, especially where the clay or gravel contains large boulders. In the installations mentioned, however, the shafts remained plumb to all practical purposes without any special attention more than is necessary in good pile driving practice. It may be added that great care is to be exercised in driving and instances have occurred, through inexperience,where it was attempted to drive the piling not to but through solid rock. With reasonable care in driving, however, this use of steel sheet piling results in economical construction.

An ingenious system of forcing down piles in lining shafts has been successfully applied on several occasions in England

and covered by letters patent taken out in the name of Mr. Charles Walker. It consists, briefly, in erecting a cylinder of tubbing which is suspended from a surface platform, and utilizing its weight to force down the circle of interlocking piles which are of special type and have riveted to them lugs or brackets against which pressure is exerted by hydraulic jacks. The verticality of the piling is assured by means of a movable or floating ring of tubbing into which they are grooved and which lies at the bottom of the shaft as it sinks into the silt. Full details of this form of construction may be

Fig. 17. Steel Framed Shaft, Newport Mining Co., Ironwood, Mich.

found in Redmayne's "Modern Practice in Mining," Vol. 2, page 197.

The standard typical framing of rectangular shafts in the United States consists of the use of timber sets spaced 4 feet, more or less, centers, as conditions may determine, and lagged between with plank. In the mining districts of Michigan and Minnesota there are quite a number of mine shafts timbered with steel shaft sets lined with plank. These shaft sets are made along the lines of the timber set and are lowered into position by hangers as the excavation proceeds. They have been constructed with tee rail wall plates, 3" and 4" I-beam buntons and rail stuttles; also with 4x5" tee wall plates reinforced by angles for proper bearing, 3", 4" and 6" double channel buntons and rail stuttles; also with 4½x5½x8" Carnegie steel cross tie wall plates with 4" Z-bar buntons and 3" I-beam compartment dividers and rail stuttles. In the evolution of these sets the strength of steel has sometimes been overestimated by the mine foreman and sections of too small depth and too little strength substituted for the wooden sets previously in use. As an engineering proposition, after the proper size of wooden timber sets has been attained by experience, it is a very simple matter to substitute steel for their use on the basis of their relative strengths, and wherever this has been done, the substitution has been satisfactory.

Fig. 17, for example, is a view of an inclined steel framed shaft constructed by the Newport Mining Company at Ironwood, Mich., in which the wall plates are made of 4x3" tees, the stuttles are of angles and the buntons of H-sections. The use of the angle stuttle is to be recommended as thereby special hanging rods may be eliminated in the process of sinking and no material go into the shaft which does not remain in place permanently. With the angle stuttle also the load is divided equally on the bearers above and below, while with the rail stuttle sometimes used the weight of the shaft comes on the lower bearers only. The H-section buntons are also in line with good engineering experience, while the use of tees for wall plates are suitable for the installation, though as a general proposition this is not the proper form of section.

A more ideal form of construction is shown in Fig. 18 which represents a five-compartment mine shaft proposed for use in the mines of the Oliver Iron Mining Company. In this construction the broad bearing surfaces and high compressive strength of the H-sections are utilized for wall plates, compartment dividers and buntons, while the stuttles are made of 3½x3x⅜" angles. 10" I-beams were used for buntons instead of 5" H-sections at the Hill Mine, Sterling Siding, Minn., so as to allow the use of steel shaft sets in connection with wood, the buntons in the wooden sets being 10x10" and 10x12"; otherwise the 5" H-sections would be much better adapted to the construction.

Recently quite a number of concrete lined shafts have been recorded in the technical press as either completed or un-

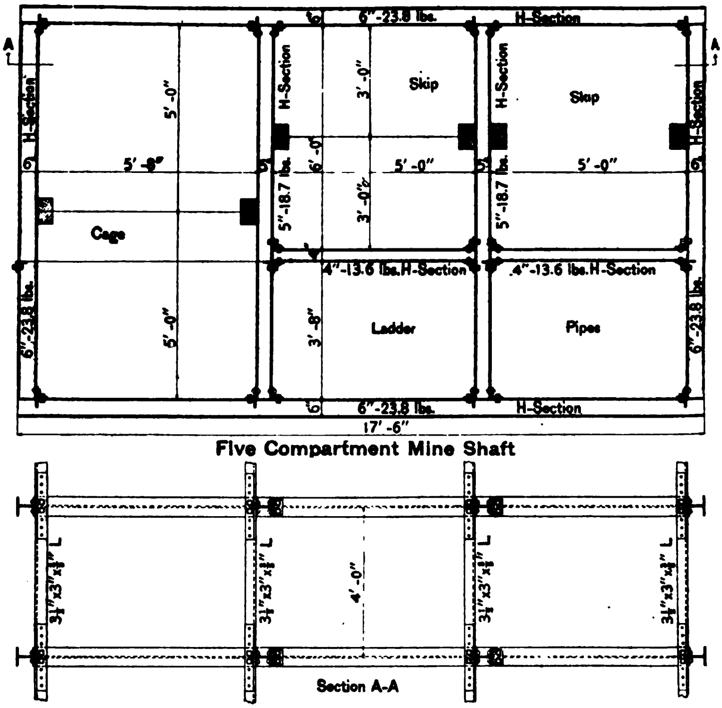


Fig. 18. Proposed Five Compartment Steel Framed Mine Shaft.

der construction. A representative example is to be seen in the shaft built by the Foundation Company for the Delaware, Lackawanna & Western Railroad Company at the Woodward Colliery about a mile from Wilkes-Barre, where an open concrete caisson was sunk through 79 feet of the water-bearing soil overlying the bed rock. The concrete caisson was constructed with a cutting edge of ¾" plate 32" high, well reinforced with riveted angles, and the concrete in the walls of the shaft was likewise reinforced with 1" and 1¼" steel reinforcing rods amounting in weight to 140 tons. Instances of the same kind are the two concrete shafts built by the H. C. Frick Coke Company at its new mines, Filbert, Brownsville, Pa., and in the iron mining regions may be cited the circular reinforced concrete shaft sunk at the Morton Mine, Hibbing, Minn., by the Foundation Company for the Todd-Stambaugh Company, Cleveland, also the shafts sunk by the same company for the Cleveland-Cliff Iron Mining Company at their Smith and Kidder Mines near Princeton, Mich. The caisson at the Kidder shaft was built upon a fabricated steel shoe 24 feet outside diameter riveted to a steel cone plate on the inside, the slope of which extended up to a height of 10 feet, making the working chamber on which were bolted steel sections 10 feet in diameter as the structure sunk.

The use of steel buntons and interior framing has much to recommend it in connection with the concrete lined shaft, as it is strictly in line with observations already made as to the relative uses of these materials. Fig. 19 shows an elliptical concrete hoisting shaft under construction at Annabelle Mine, Worthington, W. Va., by the Four State Coal Company, a subsidiary of the Pittsburg-Buffalo Company. This shaft is 340 feet deep, lined with reinforced concrete. The buntons are made of 12" ship channels 48.4 pounds per running foot, anchored at their ends into the center of the shaft lining but without special bearing plates. The two channels at the center of the shaft are fastened together by bolts and separators. The wooden guides are furnished in spliced lengths with broken joints, though this feature is not very plainly shown in the illustration.

Fig. 20 shows a plan and vertical cross section of the elliptical hoisting shaft now under construction by the Tennessee Coal, Iron & Railroad Company at Pratt Mine No. 13 near Ensley, Ala. In this case the concrete is massive and not reinforced, with a minimum thickness of 15″ through firm material and 18″ through soft. The buntons are made of

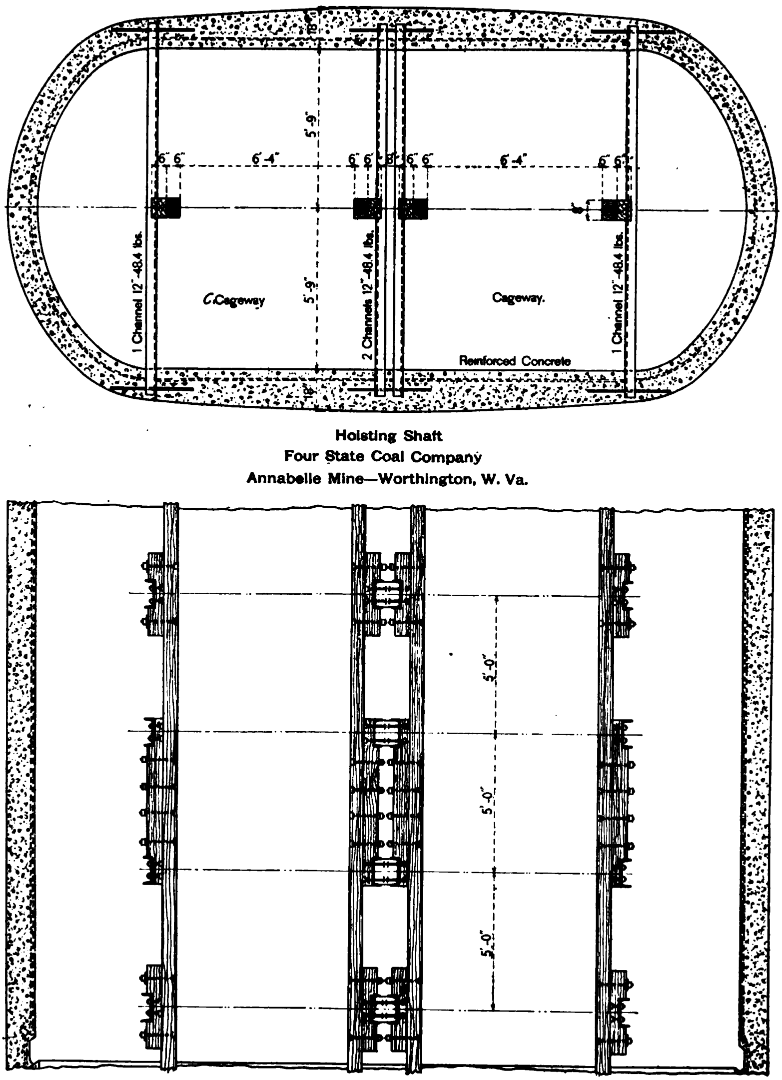
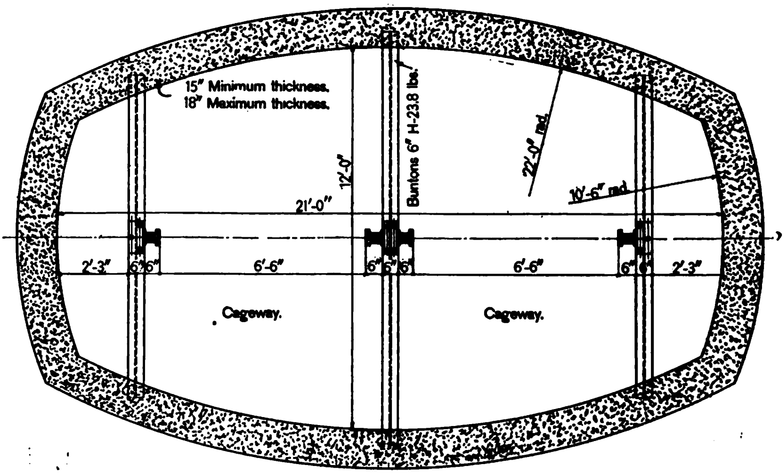


Fig. 19. Elliptical Concrete Hoisting Shaft, With Steel Ship-Building Channel Buntons.

6″ H-sections weighing 23.8 pounds per foot spaced 6 feet apart. The guides are likewise made of 6″ H-sections and carry bolted to them cast steel safety racks, insuring great stiffness and rigidity in the structure and in consequence a



Elliptical Hoisting Shaft
Tennessee Coal Iron and Railroad Company.
Mine No. 13 Ensley, Ala.

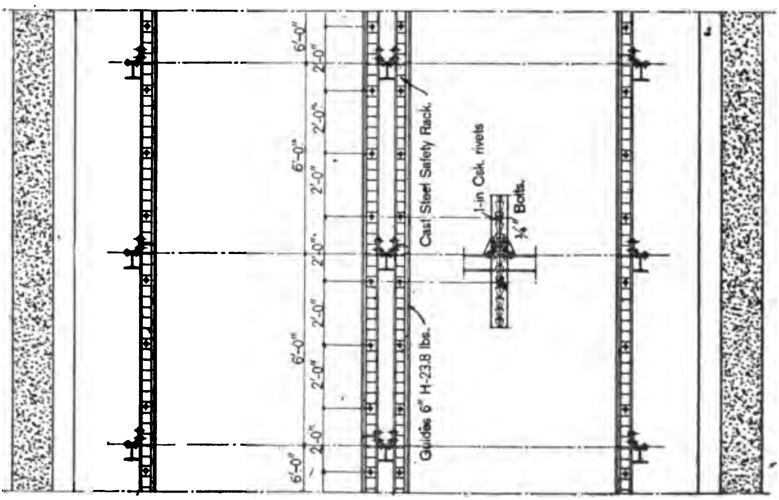
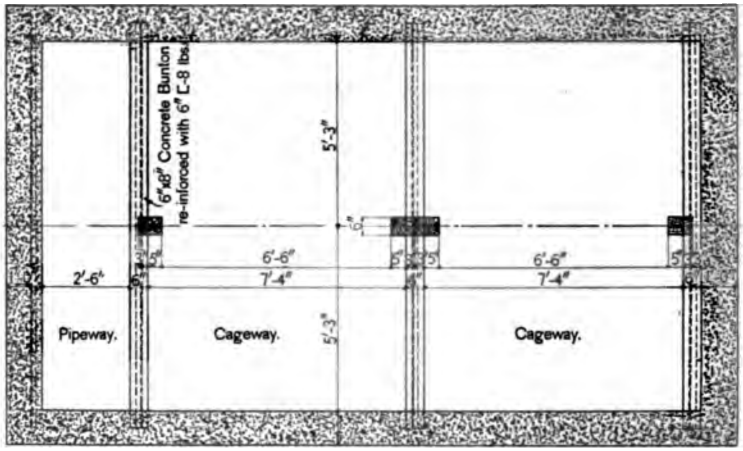


Fig. 20. Elliptical Concrete Hoisting Shaft, With H Section Buntons and Guides.

minimum of lost motion in operating the shaft. The shaft is located near a fault and the measures are much disturbed.

It is, therefore, the intention to use steel beams for roof supports in the main gangways and tunnels around the shaft.

The Bunsen Coal Company, mining coal in the Clinton



Rectangular Hoisting Shaft.
Bunsen Coal Company
Clinton Coal Fields, near Clinton, Vermillion Co, Ind.

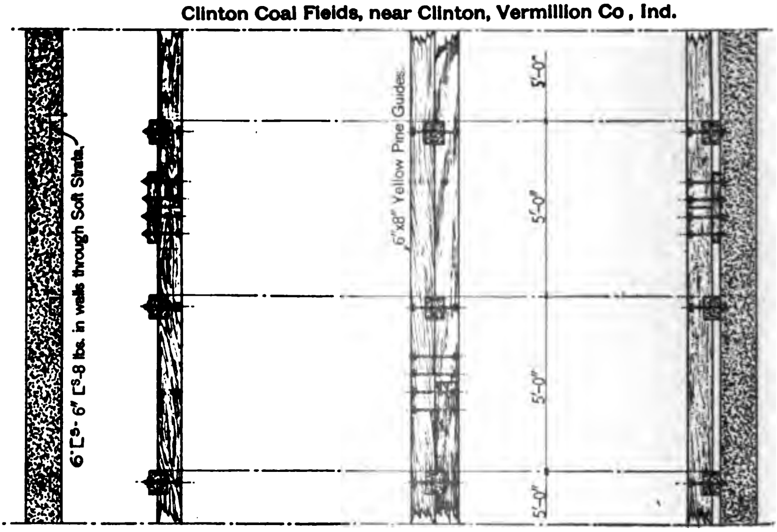
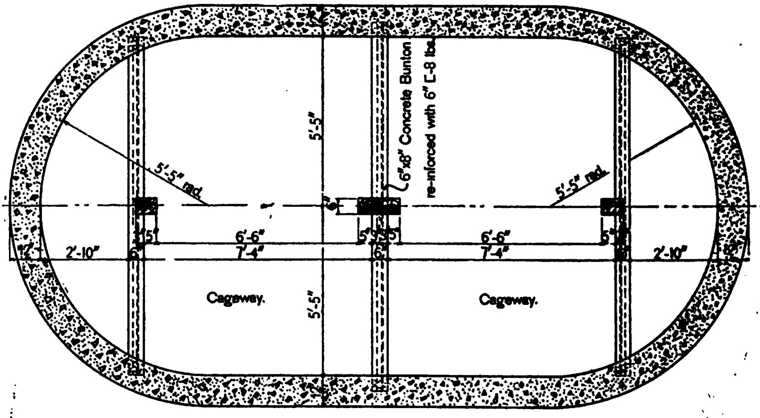


Fig. 21. Rectangular Concrete Hoisting Shaft, With Steel Channel Buntons.

Coal Fields, has a shaft under construction near Clinton, Vermillion County, Ill. Two designs for this shaft are shown in Figs. 21 and 22, one rectangular and the other elliptical. The buntons in either case will be constructed of 6x8″ concrete beams reinforced with a 6″ 8℔ channel. Where the shafts



Elliptical Hoisting Shaft
Bunsen Coal Company
Clinton Coal Fields, near Clinton, Vermillion Co., Ind.

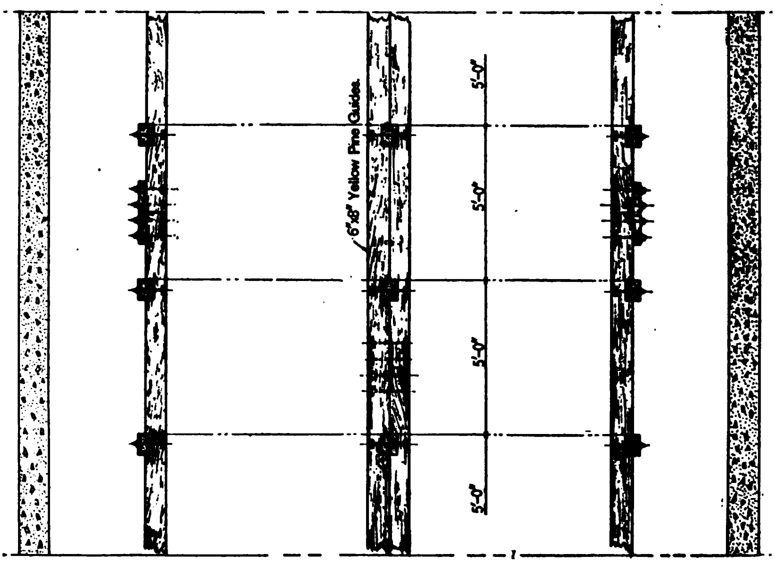
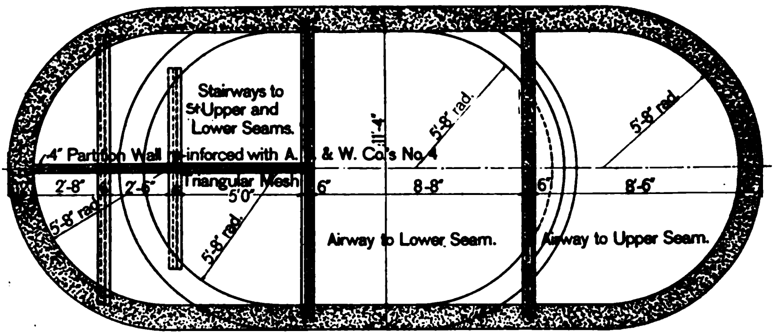


Fig. 22. Elliptical Concrete Hoisting Shaft, With Steel Channel Buntons.

pass through soft strata, it is the intention to reinforce the concrete at the ends also with 6″ 8℔ channels. The thickness of the lining will be 6″ through firm material and 12″ through soft. The guides in both cases will be made of 6x8″ yellow



Elliptical Air Shaft
with Separate Compartments to each seam.
Bunsen Coal Company.
Clinton Coal Fields, near Clinton, Vermillion Co., Ind.

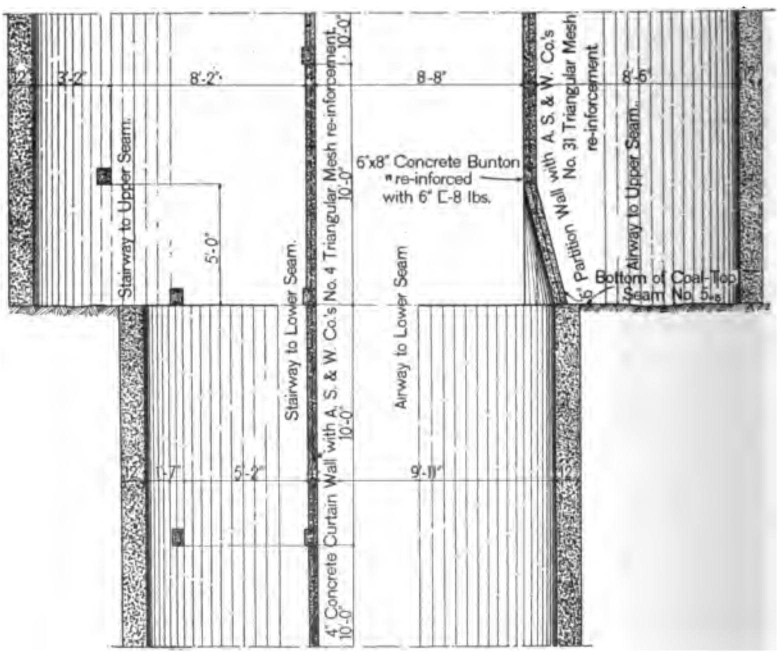


Fig. 23. Elliptical Concrete Air Shaft, With Two Compartments, Steel Channel Buntons and Wire Mesh Reinforcement.

pine timbers securely bolted to the reinforced concrete buntons. It may be noted in illustration of the observations made as to the advantages of the rectangular shaft that the shaft shown in Fig. 21 has an inside area of 196 square feet with an area of excavation for a 6" thickness of lining of 226 square feet, while the inside area of the elliptical shaft shown in Fig. 22 is 211 square feet and the area of excavation for a 6" wall thickness 240 square feet.

A most excellent illustration is shown in Fig. 23, the plan and cross section elevation of an elliptical air shaft also under construction by the Bunsen Coal Company in the Clinton Coal Fields. Two seams of coal are mined and the shaft has separate air ways to each seam, as shown in the figure. The inside area of the upper shaft is 305 square feet, and of the lower shaft 165 square feet; the outside area for a 6" wall thickness, 341 feet for the upper shaft and 189 feet for the lower shaft. The shaft is about 400 to 500 deep as also is the hoisting shaft just described. The partitions in the shaft are reinforced concrete built with the American Steel & Wire Company's No. 4 triangular mesh reinforcement on 6x8" concrete buntons reinforced with 6" 8lb channels. These partitions, however, will be made 8" thick instead of 4" as shown in the figure.

In the design of mine shaft timbers the thing of prime importance is simplicity, which lessens the cost of fabrication and contributes to ease in erection. This simplicity is a thing which has always characterized the rectangular wooden shaft. It is a thing which just as well characterizes shaft timbers of steel. Bolts should always be used for erection rather than rivets and the hangers should be, preferably, of the angle type so as to add stiffness and facilitate plumbing. For bearers nothing better can be devised than the standard steel I-beam.

An objection has been raised to the use of steel on account of its danger to corrosion. It need only be said that both the light of experience in this country and abroad and laboratory tests demonstrate amply that the subject is one of very little importance. Underground conditions are not nearly so severe on the steel as above ground conditions, and certainly painted material in the mines is not exposed to those alternating conditions of high and low temperature, dryness and wetness, strong light and darkness with which above ground construction has to contend and which are especially accelerative in the deterioration of a protective coating. The steel should be painted before it is placed in service. If the paint is well chosen and applied with care, there need be no fears as to its durability. Experience and theory all indicate that only the simplest means are necessary for the absolute guarantee of an extremely long life for steel in underground mining conditions.

The first coat applied at the shop should consist of a practically inhibitive pigment to prevent the inception of corrosion in the steel, and the second coat should be put on in the field to protect the first from atmospheric and temperature conditions, to fill up thoroughly any voids which may occur therein and to cover surfaces abraded in shipment. To meet these requirements a good grade of red lead or a natural oxide of iron well applied will be sufficient for the first coat. For a second or excluding coat there seems to be nothing better today than a first class graphite.

It appears eminently appropriate that steel should be used in the timbering of iron mines, whether in horizontal headings or in shafts, as its use simply means putting back in finished form that which has already been dug out of the mine in order to dig out more. This is not exactly a parallel to the classical problem of a man pulling himself over a fence by his own boot straps, but is, beyond question, a step towards the solution of that problem.

A DIAMOND DRILL CORE SECTION OF THE MESABI ROCKS—II AND III.

BY N. H. WINCHELL.

II. MICROSCOPIC CHARACTERS.

Since the megascopic examination was published the writer has procured from M. E. Dominique, 22 additional thin sections, making in all 106. The enumeration is the same as in the record of the megascopic characters. The depth in feet as herein expressed, is uniformly that of the commencement of the interval represented by the specimen described, viz.: thin section No. 1, representing an interval 145 ft. to 157 ft. is recorded as from the depth of 145 feet, though it actually may have been taken at any point within that interval.

No. 1—145 ft. to 157 ft. About one-third of the area embraced in the field of the microscope is composed of angular grains of quartz. There are also scattering scales of muscovite, or calcite and apparently of sphene and leucoxene. The most interesting portion is the matrix which surrounds these minerals. This constitutes more than one-half of the area of the field, and while it sometimes appears to have a chloritic green, it is for the most part colorless and practically isotropic, showing a high index of refraction. It is not free from structure, but has an irregular network of partings which sometimes cross each other, and sometimes run for short distances rudely in the same direction, but are not parallel. It contains a great many inclusions and bubbles. About the edges of the quartz grains the isotrope shows, sometimes, a reciprocal, interlocking marginal embayment, with isolated small parts of one within the other, indicating a contemporary mutual relationship.

The inference from the characters seems to be that, while the rock is fragmental, there has been a secondary growth of the quartz, accompanied by the generation of the other minerals and that apparently, the source of the elements of the new minerals is in the isotropic substance.

This isotropic substance seems to have the characters of volcanic glass partially devitrified, and hence is not totally dark between crossed nicols.

The appearance of this section is shown by Fig. 1, plate 1, and between crossed nicols by Fig. 2, plate 1. The former is magnified about seventy-five diameters and the latter about twenty-five diameters.

No. 2—157 ft. to 169 ft. Like the last, but has a larger proportion of the isotropic matrix. In isolated spots the matrix material is nearly or quite opaque, appearing like leucoxene. In that condition sometimes it spreads over considerable areas, embracing smaller areas that are not opaque and also angular grains of quartz. It may be that the distribution of this form of the matrix stuff has caused the pitted appearance of the cut surfaces mentioned in the megascopic description, but the section, as cut, does not show so much of the opaque substance as that description seems to imply.

The term "matrix" as here used is intended simply to indicate that this isotrope is the most abundant element, and that it surrounds compactly all the other minerals, although itself fragmental.

No. 10—285 ft. to 302 ft. Similar to Nos. 1 and 2, but coarser and shows more calcite and a greater proportion of angular quartz. It has, also, at least one very evident grain of some plagioclase and several sphenes. The calcite is ensconced, like the quartz, in an irregular mosaic of the isotrope. Some of the matrix is greenish-brown especially when clear and free from bubbles and other inclusions.

No. 11—302 ft. to 317 ft. This slide shows a rock consisting largely of the same element as forms the "matrix" in the foregoing (Nos. 1, 2 and 10) with not more than a fourth of the whole quartz. It is finer-grained than either of the others. There is no magnetite, but dark aggregations of minute globular bodies through which, with a high power, minute pencils of light can be seen to penetrate. There are variations in the condition of the matrix stuff. From this opacity are all stages of increasing translucency to that which characterizes the matrix in general. Other small grains are sphene, which, with mica scales and a small amount of calcite, completes the list of determinable minerals. Some parts of the slide are more abundant in quartz, as if a varying sedimentation had introduced it, and the foreign nature of most of the quartzes, although angular, is indicated, at least in some cases, by their independent boundaries. In case of the foreign origin of these quartzes, the only way to explain the occasional interlocking of their borders with the matrix is to assume that they have been subjected to a small secondary growth. The isotrope itself is finely fragmental, as well as being charged with globulites indicating devitrification from glass.

No. 12—317 ft. to 322 ft. This is a remarkably dark and isotropic slide. In the dark groundmass, or matrix, are distributed everywhere, angular quartzes, a few fine calcites, plagioclase, muscovites and perhaps sphene. The groundmass which is plainly fragmental shows variations (between crossed nicols) of translucency due to the varying amount of the translucent minerals, giving the slide a blotched appearance, the blotches being roundish and more dark than the rest. With one nicol a similar blotched structure is apparent, but some of the blotches are more light than the average aspect and some are darker, and in this case the blotched aspect is seen to be due to differences in the groundmass, some being dirty and dark and some being almost glass clear, but devitrified. The blotches coincide with and are probably caused by the pellet structure mentioned in the megascopic description. At the same time the lighter isotrope takes the form of thin, more or less wavy streamers that suggest a fluidal structure but are caused rather by variations in the manner of sedimentation.

No. 15—343 ft. to 364 ft. This slide is almost wholly isotropic, there being only a few minute grains that polarize as calcite, and a few, also very small, that are apparently of quartz, and some that may be sphene.

This isotropic mass, as cut in the slide, is permeated by an irregular, very fine mesh, which divides the field into innumerable minute parts of wholly different shapes. The mesh itself, is expressed by the Becke line, which flickers out and in about the included parts as the objective is raised or lowered, and which can be made almost to disappear by getting the exact focus so as to cover the whole field. The Becke line is indicative of variations in the refractive index, within very small limits, in the body of the rock, due perhaps to unequal shrinkage in the process of solidification, or more likely to fragmental structure in a composite sediment. It is to be noted that the Becke line plays conspicuously around groups of globulites, and isolated bubbles, as well as about glass-clear areas. Throughout the slide the bubbles and globulites already mentioned in other slides, characteristic of volcanic glass, are distributed. A portion of the fine globular inclusions appear to be incipient minerals, perhaps augite, others appear to be composed of sphene.

The characters of this section indicate an original, uniform sheet of volcanic debris, deposited as a sediment.

No. 16—360 ft. to 369 ft. The description of No. 15 applies exactly to this slide. Hence the sheet of volcanic glass (as a sediment) must have been at least 17 ft. in thickness, but appears to have been much thicker, judging from the megascopic characters of several numbers below.

No. 21—426 ft. to 438 ft. Similar to No. 15, but containing more quartz, also a little of some amphibole. All the grains also are larger. The field of the microscope is diversified by sudden splashes of opaque matter which is black, which appears only to be a form of the general matrix matter which in general is translucent. It is abundantly supplied with large translucent grains of the same substance as the rest of the slide, and contains some conspicuous quartzes. Both the quartzes, and the translucent areas have inclusions, but the translucent areas more numerously. Throughout the slide are titanium minerals, rutile, sphene and leucoxene, and crowded groups of globular microlites which cannot be specifically determined, but may be incipient calcites.

No. 24—467 ft. to 478 ft. The slide consists largely, probably more than three-fourths of the whole, of angular quartz, in grains that average perhaps one-half larger than in any of the foregoing described slides. Muscovite, calcite and leucoxene are common and conspicuous, and some sphene. These quartzes show no borders indicating secondary growths, but their edges fit with the sinuosities of the matrix in the same manner as already described. The matrix is the same as in the slides foregoing. There is a uniform direction of general elongation for all the ingredients, but this is not without exception.

No. 25—478 ft to 490 ft. This large slide contains less quartz, but consists very largely of the matrix stuff, with an occasional mica scale. Throughout are many globular inclusions, and bubbles. The matrix, in this slide is, in some of its parts, quite dirty and nearly opaque, and in its darker parts shows the pellet structure.

No. 26—490 ft to 503 ft. This is like the last, but is finer-grained and has even less quartz. Sphene and leucoxene are common, seen in convergent light and with high power objective; also muscovite and tourmaline, the last only rarely.

No. 28—515 ft. to 529 ft. This slide is also composed almost wholly of the matrix stuff, but as in other instances the translucent parts are variegated by splashes of non-transparent, almost opaque, matrix stuff. In these splashes are larger quartzes, and also grains of the translucent matrix stuff. Myriads of bubbles and globular incipient minerals. Sphene is present and leucoxene is common. The rock is wholly fragmental.

No. 29—529 ft. to 540 ft. The matrix stuff embraces many areas of calcite, in some places a fourth part of the whole being calcite. This mineral is not in large plates, but in irregular small grains, mingled with the matrix stuff, and accompanied by many globular grains of other minerals, but usually not embracing them. Sometimes over a considerable area these separate grains have the same orientation, and doubtless are but parts of single large crystals, but the matrix stuff penetrates them so as to embrace the smaller parts as in a fine mesh, but a mesh of constantly varying form and fineness.

No. 30—540 ft. to 554 ft. The description which was given of No. 1 will apply well to this slide, except that there is no common direction of elongation of the parts.

No. 32—564 ft to 579 ft. This is nearly all matrix-stuff. Between crossed nicols but few minute particles that transmit light can be discerned in the dark field. These consist of quartz, calcite, muscovite, etc.

No. 33—579 ft. to 592 ft. There are isolated areas in the microscopic field which differ in the size of the mesh mentioned, being denser and apparently less advanced in devitrification and some that shows no mesh. Such areas of finer mesh are common in all the slides, and they may be the main cause of the so-called lumpy structure mentioned in the megascopic descriptions. Dark shreds of opaque matrix stuff are conspicuous. These usually contain coarser quartzes.

No. 34—592 ft. to 603 ft. This slide differs from the foregoing in being generally much darker and in irregular areas almost opaque, and in more strongly suggesting a double source of origin. Sometimes these dark portions contain more coarse quartzes. Some areas are glass-clear, but greenish, destitute alike of Becke mesh and included minerals.

No. 35—603 ft. to 613 ft. Same as No. 34, but not so generally dark, consisting rather in general of the translucent phase of the matrix stuff.

No. 39—630 ft. to 643 ft. This is a singular rock. It has medium sized feldspars that present the general aspect of orthoclase, appearing porphyroidally, and others of plagioclase in microlitic spindle-shaped and crowded sections which commonly show irregular albite twinning, a small amount of quartz, a little calcite and a conspicuous pyroxene in elongate sections. These are minerals (except the calcite and perhaps the quartz), of the first consolidation and compose the crystalline texture of the rock. They lie in a groundmass which is much finer crystalline, consisting mainly of fine scales apparently of muscovite. There is also, besides this secondary consolidation, apparently a third consolidation, which is apparent in the presence of a small amount of what may be magmatic residuum. This is sometimes nearly opaque, and sometimes translucent, and has numerous inclusions. The pyroxene has a sub-ophitic relation to the fine feldspars.

The porphyritic feldspar of which but one sample appears in the slide, is abnormal orthoclase, twinned as Carlsbad, cut nearly perpendicular to Z in one of its parts. Z is also the obtuse bisectrix. One of the twins therefore shows no good basal cleavage (Optical Mineralogy, p. 215, fig. 100). In the other twin the angle of extinction of X varies from 41° to 44°, measured on the basal cleavage. The section shows anomalies, which suggest albite and also pericline twinning, but these are due apparently to the shattered condition of the crystal, and to a zonal structure due perhaps to chemical alterations of which the introduction of soda was probably the chief.

Further, in regard to this feldspar, there are two places where the sign is distinctly positive, a condition unknown in orthoclase or soda-orthoclase, except for Duparc's isorthoclase. If it be allowed that soda has in part replaced the potash this will give in part an abnormal soda isorthoclase. These irregularities are perhaps ascribable to heating and shattering subsequent to the first consolidation.

The same feldspar appears crowded amongst the microlites in anhedrons and is uniformly positive. This rock needs further study.

The microlitic feldspars are also negative, having Z in the obtuse angle of the optic plane, indicating an alliance with the anorthite end of the feldspar scale rather than the albite end, but the maximum equal extinction angle is about 13°, indicating oligoclase.

The green mineral has resulted, probably from an alteration of augite, mainly from the introduction of soda. It is acmite, with negative elongation.

The general aspect of the rock shows that the crystallizing process was confused and interrupted. This is indicated by the sudden variations in the forms of the crystals. Some of the small feldspars are bent, and in nearly all cases they are distorted so that the albite twins are not in agreement from one end to the other.

Occasional grains probably of nephelite are seen. They are practically dark between nicols, but white and glassy translucent in ordinary light, with low refringence.

This rock probably occurs as a dike, and may be compared with the "soda granites" in the northeastern part of the state.

No. 42—682 ft. to 692 ft. About half the fragmental grains are of the matrix stuff, already mentioned. The most of the rest are fine angular quartz, a little calcite, scattered grains of leucoxene and groups of indeterminable globulites, the last embraced within pieces of the matrix stuff.

No. 45—720 ft. to 735 ft. Finer grained than No. 42, and with almost no quartz, but with shreds of dirty matrix stuff. The field is almost wholly dark between crossed nicols, yet the rock is a fragmental one. In the matrix stuff are innumerable fine globulites.

No. 46—735 ft. to 744 ft. Like No. 42, but a little coarser, and with a few shreds of dirty matrix stuff, also many small bits of the same of about the same size as the quartzes. The matrix stuff varies in opacity and in the number and size of the included globulites, and some of it is of a dirty green or dirty yellow color without evident globulites, but crossed by seams, apparently shrinkage cracks.

No. 48—757 ft. to 768 ft. Finely fragmental and mainly isotropic, but having a few grains of quartz and spicules of actinolite, scattered and also grouped sphenes and some mica. The section is cloudy with numberless dark impurities, and blotched with shreds of opaque matrix stuff.

No. 51—793 ft to 805 ft. This slide contains numerous coarser grains of angular quartz, considerable calcite, a few scales of muscovite (?) and more of biotite. In this slide are many shapeless splashes of dirty matrix stuff. The quartzes are reshaped by secondary growth so that their margins somewhat interlock with the matrix stuff. The constituent grains do not now show detrital shapes although plainly the rock is of fragmental origin.

No. 56—840 ft to 890 ft. This is like numerous slides already described. It has even more dark matrix stuff than No. 51. This is in large areas and also is disseminated adundantly in finer sizes throughout the slide. The microscopic globulites, so far as they are visible seem to be more abundant in the lighter matrix stuff.

No. 58—859 ft. to 871 ft. Like No. 51, but lacking the conspicuous black splashes though still some small ones are seen.

No. 62—895 ft. to 898 ft. The slide consists almost entirely of the isotropic matrix stuff, but it is fragmental, embracing quartz, calcite and some mica, also finely granular, brown sphene; also leucoxene.

No. 64—918 ft to 925 ft. Made up of the usual matrix stuff and fine grains of quartz and other minerals already mentioned, and some dark irregular patches of dirty matrix stuff. This slide, in high power and high light, between nicols appears to be finely fragmental, showing quartz, calcite, mica, and mainly a finely comminuted dark colored isotropic substance; which last, is responsible for the general isotropic aspect of the slide in low power. These fine ultimate grains are all angular and are the cause of the fine mesh of Becke lines.

No. 66—939 ft. to 954 ft. Same as nearly all the preceding. The fine, fragmental angular aggregate can be seen in high power, high light and between crossed nicols, the concentrator lens close under the stage.

No. 67—954 ft. to 965 ft. Same as nearly all the preceding, but the fragmental quartz, though angular, is abundant and much coarser and is accompanied by some plagioclase; and has also been enlarged by secondary growth. The isotropic part is less than one-half.

No. 68— 965 ft to 975 ft. About one-fourth of this slide is made up of the usual matrix stuff. The quartz grains that have been enlarged, though of three and four times the usual size, interlock with the isotropic grains. Amongst these grains can be seen several of plagioclase and much calcite. There are also shreds of opaque matrix stuff, and of a brown, finer grained matrix stuff. The calcite sometimes poikilitically embraces the quartz. The matrix stuff is sometimes brown glass, but usually is crowded with microlites.

No. 69—975 ft. to 985 ft. Dense but fragmental and mainly isotropic, with numerous scattered points where, between crossed nicols, light can be seen to penetrate. It also has a few pieces of dirty, opaque matrix stuff; a sedimentary rock, in which the fragmental isotrope is intimately mingled with angular guartz (mainly), but also with calcite, muscovite, apparently sphene, and with semi-devitrified isotropic stuff.

No. 76—1055 ft. to 1065 ft. About one quarter of the slide is composed of dirty, opaque, matrix stuff, in patches rather evenly distributed amongst the translucent matrix stuff, and many angular quartzes, some mica and less calcite.

No. 78—1075 ft. to 1085 ft. This slide shows only a little variation toward the dark matrix stuff, which is usually devitrified and accompanied by scant grains of foreign quartz. It is quite like No. 76.

No. 82—1109 ft. to 1115 ft. The slide consists mainly of grains of the dirty, opaque matrix stuff. Distributed with it are angular grains of quartz, and many grains derived from the matrix stuff of a different color, some of it being brown, and imperfectly translucent, and others of much finer grain, denoting a mixing in some way, of pieces of the matrix stuff which were older with those that furnished the most of this slide. The striking feature of the slide is its dark and prevailingly opaque appearance, the polarizing grains being embraced apparently in an opaque mesh.

No. 88—1131 ft. to 1141 ft. So similar to many others that this slide does not need special description. It is very fine-grained.

No. 90—1152 ft. to 1160 ft. A fragmental rock of very fine texture. Between crossed nicols small quartz grains are scattered in a nearly dark field. They are enlarged by secondary growth, presenting interlocking margins. The rest of the sediment is evidently of the same nature as the matrix stuff of the associated slides.

No. 92—1170 ft. to 1177 ft. This slide consists in the main of two phases of the matrix stuff, one being translucent and like those already described, with angular quartzes, globulites, leucoxene, calcite (apparently one apatite) and mica, and the other, which embraces about one-fourth of the slide, of the opaque dark matrix stuff, containing the same minerals but a larger proportion of calcite. The dark portion also embraces small grains of the light matrix stuff.

No. 97—1215 ft. to 1226 ft. The slide consists of essentially the same elements as the most of those preceding. The dark matrix stuff, while appearing as a fine shapeless powder or dust disseminated throughout the slide, also is in larger and darker bunches or areas. In all cases it is charged with fine polarizing grains, including also grains of the translucent matrix stuff, and it embraces them all as a kind of mesh.

No. 98—1226 ft. to 1237 ft. There is apparent an important change in the structure and composition. The most of the slide is translucent and composed of abundant subrounded grains of uniform size of quartz and of the light matrix stuff, along with some calcite and a little plagioclase. These are embraced in a sparse matrix that appears to be the same as the dark matrix stuff. It is apparent in this slide that in concentrated light, in high power, the light matrix stuff is far from isotropic, but that it is charged with minute crystallites, by which a considerable light is transmitted.

No. 102—1263 ft. to 1271 ft. The description of No. 97 is applicable to this.

No. 105—1285 ft. to 1295 ft. While mainly homogeneous and composed almost entirely of isotropic materials, with quartz, calcite, mica, leucoxene, etc., this slide has two or three kinds. These kinds slightly differ in translucency and in the fineness of their contained grains, and they are distributed and bounded in such a manner as to suggest an original fragmental origin. The quartzes also are not prevailingly interlocked, about their peripheries, with the isotropic parts, but are distinctly bounded, although angular. Opaque cubes (magnetite?) replace the darker matrix stuff in some places.

No. 110—1319 ft. to 1329 ft. This slide contains considerable fragmental quartz. Calcite is abundant in grouped small grains and in larger crystals that sometimes exhibit their complete crystal outlines. Mica is not uncommon, but more than half the slide is isotropic. Actinolite is in sheaf-like aggregates. Some of the isotropic material is glass-clear and some is dirty-opaque. The sheaf-like actinolite groups are in the former.

That which is here called isotropic appears, in convergent light, to be partially crystallized and allows the passage of some light. This feature is observable by the use of the highest power objective.

No. 118—1383 ft. to 1398 ft. This slide shows a probably fragmental rock, in which the fragmental materials were largely isotropic or sub-isotropic and were not much worn by transportation prior to first deposition. It contains also angular or sub-rounded quartzes and several grains that appear to be apatite, being highly refractive, glassy-translucent, and short-elongated.

No. 121—1401 ft. to 1407 ft. This rock is similar to No. 118, but more evidently formed by quick fragmental accumulation of sub-isotropic grains of differing translucency and size. It also contains much calcite. More than one-half of the whole slide is composed of such sub-isotropic grains, the most of the rest being quartz and calcite. There is a conspicuous, dark, opaque matrix of all the foregoing, which itself constitutes more than the matrix, rising into irregularly shaped masses as if accumulated as a part of the sedimentary deposition.

No. 123—1414 ft. to 1422 ft. This rock, while very dark colored, and largely opaque, yet aside from its matrix is composed of quartz and of fragments of differing opacity, and fineness of grain. These fragments are sub-rounded, and amongst them as well as embraced in them, are sub-angular small quartzes, as well as calcite and mica. In the quartzes are many bubbles, and other inclusions. The source of this dark isotropic material is problematic, but may have been preexisting fields of differing kinds of volcanic lava, but not including much volcanic translucent glass. It is evident that the existence of these rounded, or sub-angular lumps of volcanic rock may be the cause of the internal globular structure mentioned in the megascopic description.

No. 126—1435 ft. to 1443 ft. The slide contains some subangular grains of quartz and a little calcite but the most of the field is dark in parallel light, between crossed nicols. This isotropic substance is mainly translucent, but some of it is nearly opaque. It is entirely fragmental.

No. 127—1443 ft. to 1447 ft. Same as No. 123, but has somewhat more of the translucent matrix stuff.

No. 128—1447 ft. to 1449 ft. This rock is a fine grit composed very largely of rounded grains of translucent matrix stuff, with abundant calcite and quartz, the latter having sometimes been enlarged by secondary growths so as to partially embrace the rounded grains of volcanic glass, giving it an interlocking outline. The grains of volcanic glass have maintained their original outlines, but have become more coarsely devitrified, and sometimes largely replaced by granular calcite.

No. 130—1459 ft. to 1462 ft. This slide shows a variety of structures, all illustrating the conditions of accumulation, and the kinds of volcanic glass.

(1) An elongated pebble, with rounded contours, consisting of a dark glass finely devitrified. (Upper margin of the illustration. Fig. 1, plate 11).

(2) A mass about 10 times the size of the last, also with rounded outlines made up of fine fragmental grains and shreds of devitrified glass with many fine angular quartzes, mica scales and calcites. One portion of this shows only grains of rather uniform size, sub-angular, but the larger portion has an imperfectly parallel elongation of the larger grains. (Body part of figure 1, plate 11).

(3) Lying in the margin alongside of both of these is a black opaque glass, with only a few translucent microlitic forms that are apparent. This is massive.

(4) A nearly black fragmental devitrified mass, in the midst of which are variations in the opacity and in the fineness of the devitrification, in rounded areas, denoting detrital accumulation earlier than the present.

(5) A (comparatively) large piece of fragmental translucent devitrified glass, along one side of which is apparently a streamed structure in the midst of which are a great many microlitic and skeleton structures, as well as differing grains of glassy magma probably from different lava sheets.

(6) Three pieces of glassy magma which are in part opaque and black, through the black part passing many fine transparent lines that apparently mark out incipient crystals. These transparent lines mark out, and also include small angular parts of the black glass, as if of the nature of skeleton crystals.

(7) A pebble mass, made up, on one side, of dark glass, but in the main of a compound rock, the constituents of which are small pellets of clear translucent, hardly devitrified glass.

(8) The largest grain of the slide is of material similar, but not identical with that of the small constituents of the compound grain last described.

This is plainly a fragmental volcanic breccia some of which has suffered two periods of detrital accumulation. Figure 2, plate 11 shows an average aspect of the slide.

No. 132—1467 ft. to 1471 ft. The description that has been given of Nos. 1, 2, 10 and 11, especially No. 11, will apply equally to this rock, except that the quartz is finer and scant, compared with those, and apparently is of fragmental origin although angular. Indeed the general appearance of this slide indicates a sedimentary origin for the whole, only excepting the calcite. More than one-half consists of sub-rounded isotropic grains, probably devitrified glass.

No. 133—1471 ft. to 1475 ft. This is almost entirely free from quartz. It is mainly one substance, translucent matrix stuff. But scattered loosely throughout it are grains of less translucent matrix stuff. These usually have distinct gently rounded outlines, and frequently a finer reticulation of the Becke line, indicating a slightly different source, but one of essentially the same nature as the main part of the slide. With a low power, between nicols, the structure, as denoted by the distribution of the light lines and the shapes of the darkest grains, has a short-parallel elongation in one direction, probably due to sedimentation. The aspect of this slide favors the idea of the sedimentary fragmental manner of accumulation of the rock of slides No. 1, 2, 10 and 11, and others like them.

No. 134—1475 ft. to 1477 ft. Composed almost entirely of isotropic debris, showing slight variety of grain and structure, evidently a compacted fine debris; but in concentrated light and high power showing a few fine calcites, quartzes and mica (?).

No. 135—1477 ft. to 1483 ft. This is like slide No. 133, but affords a more pronounced indication of sedimentary origin, there being a great variety in the opacity of the isotropic grains, though their forms are usually roundish, and mingled with them are angular quartzes, and other minerals. The rock is evidently made up of debris of volcanic glass in isolated, sub-rounded fine grains more or less devitrified.

No. 136—1483 ft. to 1487 ft. Quartz and calcite are abundant in this slide, the latter not in distinct crystalline grains, but in ragged and more or less aggregated fine grains so overlapped and mingled with the next that the high polarization characteristic of calcite is not always evident. The third important ingredient is that which is isotropic and has been called matrix stuff. It is generally translucent, but evidently fragmental, judging from the mesh-like frequency of the Becke line. It composes about one half of the whole.

No. 138—1488 ft. to 1491 ft. Very much like No. 136, but having more, and more coarse, calcite and less quartz.

No. 139—1491 ft. to 1495 ft. While this is essentially the same as the last, it contains very little calcite, and consequently is almost wholly isotropic, the isotrope at the same time being largely dirty-opaque.

No. 140—1495 ft. to 1502 ft. This is almost entirely isotropic, but plainly fragmental. In high power some of the fragments appear large, extending half way across the field, and like sub-rounded pellets. They are always more or less devitrified by the generation of minute globulites, some of which appear to be calcite. Some of these pellet-like isotropic pieces are so altered that they present a dimly polarizing mosaic of fine grains of some new mineral, probably quartz in some cases and apparently calcite in other cases.

No. 141—1502 ft. to 1506 ft. While the isotropic translucent matrix-stuff composes perhaps one fourth of this slide in grains that are of irregular shapes and appear to coalesce so as to form a uniform mass, yet, not only are there grains and masses of nearly opaque matrix stuff and a few of fine quartz, but by far the most abundant and conspicuous element is calcite, which constitutes idiomorphic crystals (for the most part) which have been generated alike in the translucent and the non-translucent matrix stuff (See plate III, fig. 1). This calcite has been generated in part since the formation of a little vein of quartz that crosses the slide from side to side, for they do not interrupt the vein, but also in part prior to the vein, since they replace the vein. By this fact are they proven to have been generated in the rock in situ, as well as by the fact that in some cases a single calcite crystal lies partly in the translucent and partly in the non-translucent matrix stuff.

Throughout the matrix stuff are secondary fine quartzes, and an incipient grouping such as described in the next.

No. 142—1506 ft. to 1508 ft. There is a very fine siliceous groundmass of angular and interlocking quartzes, in which there is an undulatory structure which may have been derived from sedimentation or from shearing, but suggests an igneous fluidal origin. In numerous places throughout the slide the quartzes are much enlarged and form groups about the same size as the fragmental roundish grains, already mentioned, of the matrix stuff, seen in many slides. In these groups the quartzes are conspicuously interlocked, and lie in all orientations. Also, there are conspicuous idiomorphic calcites that lie in the ground mass, but never appear in the grouped coarse quartzes. Their size and appearance are identical with the same in slide No. 141, and they must have been generated here, as there, from the surrounding matrix. There is in this slide also a little quartz vein crossing the slide. This slide exhibits a more advanced crystallization of the matrix stuff than that of No. 141, and the two together show conclusively that the matrix stuff is the source of the quartz which here is the bulk of the groundmass and also of that which is in groups. They also show that the groups of quartz in both rocks coincide in their distribution substantially with the distribution of the subrounded grains of the matrix stuff.

No. 143—1508 ft. to 1511 ft. In this slide the calcites and the quartzes are heterogeneously mingled. The matrix stuff as such is almost lost by the generation of calcite, quartz, etc., though there is still a noticeable amount of isotropic substance which embraces innumerable fine quartzes. This is to be distinguished from another secondary substance which is also isotropic and nearly free from inclusions, (except magnetite) light yellowish-green and interlocks with all the other ingredients. This is not abundant, indeed is rare in this slide. In it, (and to some extent in the calcites) are microscopic cubes and tetrahedra of magnetite, which mineral also appears in grouped aggregates. The refraction of this isotropic secondary product is about the same as that of the matrix stuff. Its structure also approaches that of the matrix stuff, and indeed it seems to pass into it sometimes.

The order of generation of the secondary minerals appears to be as follows:

1. Quartz.
2. Calcite (and quartz).
3. Magnetite (and quartz).
4. Secondary isotropic substance.

No. 145—1514 ft. to 1516 ft. The slide consists entirely of calcite in small crowded and irregular grains. Sometimes the mass is darkened by small remnants, apparently of the matrix stuff in the interstices. There is also a single rutile, twined. This fine calcite seems to lie in an isotropic matrix, which, with a simple hand-magnifier gives the slide a faint greenish tint.

No. 146—1516 ft. to 1517 ft. Fine grained, angular and interlocking quartz, varying to coarser grained and having a small quartz vein, constitutes this slide. There is also a little calcite in fine almost globular isolated grains, and in groups.

No. 147—1517 ft. to 1518 ft. A fine mosaic of secondary quartz, sometimes varying to coarser quartz, surrounds numerous perfect calcites which have been disturbed along their cleavages, and somewhat irregularly rebuilt, and restored round their margins.

No. 148—1518 ft. to 1523 ft. In an isotropic very finely fragmental or devitrified field are larger angular and rounded bits of opaque matrix stuff, scattered small calcites, quartzes, a sub-rounded but oblong space filled with a secondary light-green isotrope, which has been called secondary matrix stuff, a vein consisting of this light green isotrope along the sides and a band in the center which is composed of calcite and an imperfectly polarizing coarsely fibrous mineral having positive elongation. The secondary matrix stuff has higher refraction than the original matrix stuff.

No. 149—1523 ft. to 1524 ft. Evidently originally a fragmental rock entirely composed of basalt pebbles, more or less devitrified and differing as to grain and degree of alteration, now charged with idiomorphic calcites. One of the original pebbles is free from the calcites, but is finely sprinkled apparently with quartzes.

No. 150—1524 ft. to 1527 ft. Crystals of calcite often zoned are idiomorphically distributed through a structureless isotropic light green substance, and through the adjoining mainly devitrified dark isotropic matrix stuff, but of less size and number in the latter, in both matrices accompanied by a few grains of quartz, which are much finer in the latter. The border line between these two isotropes is usually quite distinct, but reciprocally embayed from one side and the other, isolated portions of the matrix stuff reaching far into the green substance, but the green substance penetrating but little into the matrix stuff. The matrix stuff shows the waving short dark lines which have been noted before (in No. 133) elongated in the same direction. In a high power these are seen to consist of shreds of dark, even opaque, matrix stuff, and to fade out into the matrix stuff in which they lie. The field is blotched, non-conspicuously, with darker and lighter roundish areas, and with finer and coarser devitrification in roundish areas. Closely examined in high power the field is seen to contain small areas of the structureless green substance mentioned above, which is also evidently the same as the secondary isotropic substance mentioned in No. 143. These two are thus allied to the matrix stuff in an identical manner and were both doubtless the result of devitrification and alteration of the matrix stuff and are probably the same thing.

Further, in examining the green isotropic substance in a strong light from the mirror, it is apparent that it is not wholly isotropic and structureless, but contains fibrous growths and shorter forms of some mineral that has low birefringence and that extinguishes about parallel with its own elongation.

This green substance was the latest of the products from alteration of the matrix stuff. It is not a mineral but a nearly amorphous residuum from the matrix stuff.

No. 151—1527 ft. to 1537 ft. The whole slide is occupied with rounded shapes, like pellets, with distinct outlines. These are mainly composed of secondary quartz which is very fine in the interior of the pellet-forms, but much coarser in the interstices. In the latter position the quartzes are elongated uniformly perpendicular to the periphery of the pellets. In the larger interstitial spaces the quartzes are coarser and lose their orientation perpendicular to the peripheries. Besides the pebbles which are wholly converted to quartz, there are others which are in part, and some which are entirely converted to a substance which is isotropic, and is plainly the same as the remnant which has been called secondary isotropic substance. It is light greenish and greenish yellow, not entirely structureless, but irregularly aggregated and on lowering the condenser, shows a finer curdled aspect of confused granulation, and is not infrequently associated in the interior of the pellets, with opaque iron oxide—or at least with an uncrystallized black substance indistinguishable from iron ore. This greenish gray isotropic substance appears to be Spurr's "glauconite" and shows the same intimate connection with the iron, but an association not of genetic relationship, but of unity of origin and sameness of location. About all these grains, however fine, the Becke line makes a characteristic display.

There is also more or less calcite in crystal form, and also in a little vein where it is associated with quartz, and there are a few scattered highly polarizing fine spicules which sometimes are arranged in a star-shaped radiation.

No. 152—1537 ft. to 1543 ft. Uniformly finely fragmental or uniformly devitrified matrix stuff. A few idiomorphic calcites are distributed, but much more iron ore which also shows its cubic outlines. Owing to the uniformity and the fineness of the Becke mesh it seems likely that this rock is an original basalt, in which, along with the generation of iron ore and calcite, the whole mass has been very finely devitrified.

No. 153—1543 ft. to 1550 ft. This rock is composed of the familiar rounded grains which characterise bloodstone and much taconyte. They are mainly composed of very fine secondary quartz, which is so nearly dark between the nicols that it suggests the presence of much opal. They are clouded with the same yellowish green isotropic substance as mentioned in the description of Nos. 150 and 151. They are also accompanied by black, opaque iron ore, some of which is structureless (so far as discoverable) and some is in cubes. When this structureless opaque iron ore (or iron ore and the green substance combined) completely fills the area of one of the rounded grains, there are developed about the periphery, a multitude of highly polarizing spicules which radiate outward all about it, and such spicules, in isolated groups, also take the form of sheaves in which the spicules seem to cross each other at the center. Similar spicules are also isolated and scattered throughout the slide. They may for the present be considered actinolite. In a vein calcite is the chief ingredient, showing polysynthetic twining. Another vein is composed of quartz and iron ore. It crosses the other.

No. 155—1560 ft. to 1565 ft. Similar to No. 153, but having a larger proportion of the greenish yellow isotropic substance. Iron ore also is seen in nearly all the pellets. Some of the quartz is in fibrous radiating spicules, giving a continuous dark cross when rotated between the nicols. These fibers are positive in elongation, forming quartzine. Calcite forms several little veins and also isolated crystals. Iron ore shares with the greenish isotrope in filling another vein, but in this case the isotropic substance has fibers of quartz which show a faint light between the nicols. These supposed quartz fibers have a negative elongation and hence are chalcedony. Quartz and the greenish-yellow substance are together in all the pellets, sometimes intimately mingled.

No. 156—1565 ft. to 1567 ft. Similar to the last, but the quartz is, in part, especially in the interstices of the pellets, much coarser. In other pellets it is finer. One large pellet contains much actinolite. The iron ore is frequently crystallized, and the coarse quartzes contain many inclusions.

Throughout the slide is disseminated much of the greenish isotropic substance, especially within the areas of the pellets. Calcite is scarce or wanting.

No. 157—1567 ft. to 1573 ft. The forms of the pellets are much less distinct, but it is evident still that originally the rock was composed of pellets. The quartz is very fine within the pellet areas, and in the interstices it is frequently fibrous and radiating, forming the variety called quartzine. Calcite is scant.

The new feature of this slide is the frequent occurrence of actinolite, which is scattered promiscuously, but especially affects the margins and near vicinity of the iron ore grains. It is sometimes in sheaf-like bunches and with one nicol it almost disappears when the little spicules run right and left, but become quite conspicuous by differential absorption, when rotated so as to run north and south. They have nearly parallel extinction.

No. 158—1573 ft. to 1579 ft. Iron ore constitutes the most of this rock, but in the slide can be seen numerous calcites distributed porphyroidally throughout it. Actinolite spicules are abundant, especially in certain areas where the iron ore runs low grade. In some parts of the slide the calcites are filled with inclusions, and in some cases are so loaded with non-polarizing substances, as to become non-identifiable, and the same is true of some of the quartz. This non-polarizing substance is nearly or quite isotropic and apparently of the nature of the matrix stuff already noted. Its index of refraction, as shown by the Becke line, is less than that of the calcite. When the iron runs low grade it is because of the intermixture of this secondary isotropic substance and actinolite.

No. 159—1579 ft. to 1585 ft. Mainly quartz and iron ore, the former being usually (comparatively) coarse, but still varying in fineness so as to indicate an original pellet-structure for the rock. Some of the quartz is free from inclusions but some is crowded with them. Actinolite is common, and calcite surrounds some iron ore.

No. 161—1592 ft. to 1597 ft. Under the microscope the forms and sizes of the original pellets are clearly discernible. Some of these pellets are now converted entirely to iron ore, but the most of them are changed to interlocking granular quartz, some of them having coarser quartz than the others. In some of those nearly converted to quartz the quartz grains are exceedingly fine and seem to lie in a matrix that is isotropic, so that the pellet is not wholly transparent between crossed nicols, and with one nicol shows a shagreen with much actinolite. Actinolite in sharp spicules radiates from the edges of many of the pellets, especially from those in which very fine actinolite, calcite and quartz have replaced the original glass of the pellet.

No. 165—1613 ft. to 1619 ft. The forms of the original pellets are perfectly preserved when examined with one nicol. Some are mainly iron ore, some are of green isotropic substance charged with globular calcites and some, the majority, are changed to quartz, whose coarseness changes from pellet to pellet, and when very fine obscured by the prevalence of the isotropic substance mentioned. In one pellet a single calcite orientation covers nearly one half the pellet embracing iron ore and quartzes and a multitude of globulites, the last probably dating from the original glass.

In some cases this so-called secondary greenish isotrope, or a substance resembling it, when free from inclusions is resolved in high power and strong light into a finely fibrous mass, whose fibers are curved and parallel and present a shadowy extinction without polarization colors—but in other cases polarizing brilliantly. It hence seems true that actinolite in minute spicules is responsible for the greenish color in some grains, and that its brilliant colors are screened, sometimes, by the abundant secondary matrix.

No. 167—1629 ft. to 1633 ft. This slide presents a new feature in the relation between calcite and the matrix. The matrix is isotropic, perhaps a secondary product, but probably of the nature of the original volcanic glass. It is crowded with globular and aggregated incipient calcites. These globules are so small and so overlapping that without using the very best power, it is but rarely that a mass is sufficiently large to disclose the high double refraction of calcite. There is no quartz, nor actinolite nor iron ore. Between crossed nicols these globular calcites cause a rough inter-mixture of light and dark. The refractive index of the globulites is higher than that of the matrix.

This segregation of calcite being the only one visible shows that when devitrification first starts, at least in the conditions surrounding this rock, lime is abstracted from the glass and unites with carbonic acid, the latter being derived of course from the oceanic waters. This rock was either a massive glass, or more likely a fragmental one composed of exceedingly fine basalt pellets, and in the latter case it has become densely consolidated.

In other parts of the slide there is almost nothing but calcite, in crowded, angular, fine grains—indeed this composes the greater part of the slide, but even then can be seen remnants of dirty, opaque stuff which serves as a sparse matrix of the calcite grains.

No. 168—1633 ft. to 1637 ft. This rock, so far as shown by the slide, is composed of quartz and calcite, interlocking one with the other, but the calcites are sometimes large. There are variations in the fineness of the quartz such as indicate an original pellet structure. Spicules of actinolite stand out from the edges of some of the darker grains. The calcite is not only in the form of large crystals, which are clouded so as to show but feebly the characteristic colors of double refraction, but also in isolated small grains disseminated through the quartz, and these are more clear. The large calcites are also very often surrounded by a narrow border of clear calcite of secondary enlargement and this enlargement resembles the isolated small crystals. Here then, calcite grew first, in the order of generation from the matrix, and later, when the quartz was formed, additional calcite was formed about the older calcite crystals and fresh crystals in great numbers arose in the midst of the quartz and cotemporary with it. The large calcites also appear to have been shattered and loosened along their cleavages so as to show overlapping of parts and hence a shadowy extinction.

No. 172—1656 ft. to 1666 ft. This rock is almost identical with No. 167, but the calcite is finer grained and there is a sparse amount of iron ore, and some quartz. Quartz and calcite with a little actinolite, also fill a little vein. With a high power a few spicules of actinolite can be seen to pierce the finer quartzes that surround the iron ore.

No. 173—1666 ft. to 1670 ft. Mainly quartz, with a liberal sprinkling of fine grained iron ore and a little calcite. The interlocking quartz shows by its distribution and varying fineness, an original globulo-pellet structure. The iron ore is in crystalline forms.

No. 175—1677 ft. to 1688 ft. This is a rock in which the matrix stuff was fragmental, sometimes in pellet shapes, but it has been broken and veined and wholly metamorphosed. The matrix stuff is now largely replaced by very fine quartz and by short actinolites and fine calcites. Other actinolites are in veins. Coarser interlocking quartz surrounds the pellet shapes.

No. 176—1688 ft. to 1693 ft. This slide is mostly opaque with finely granular iron ore. Openings through the ore admitting light are crowded with granular calcite and some spicules of actinolite. Along with the calcite in these openings occasionallv can be seen some of the light-green secondary isotrope; but with strong convergent light this shows minute inclusions as well as a dull illumination. Some of these inclusions are long-fibrous actinolite and some are apparently globular calcites.

No. 177—1693 ft. to 1703 ft. The fragmental character of this slide is evident, but the original fragments are wholly altered, the products being green secondary matrix stuff, actinolite, quartz and iron ore, the last in cubic grains, both scattered and aggregated into large clusters. Some rounded pellets are of large size, and are altered entirely to the green secondary matrix stuff, though still sometimes embracing a little iron ore. Other parts consist of finer sediments, and are more generally changed to fine quartz and actinolite with a little calcite.

No. 178—1703 ft. to 1709 ft. The most prevalent element is quartz, interlocked with itself and with the next. The next appears nearly or quite isotropic, of a dirty yellowish-green color, with a finely shagreened surface, this surface being due to the incipient generation of numberless globulites, probably of calcite. This green substance accommodates itself very largely to the shape of the quartz, in a kind of streaming, and when so disposed it is marked by the presence of a great many actinolite spicules which lie generally parallel with the streaming. Such spicules less commonly pierce the quartz; also a few grains of calcite and more of iron ore in crystalline form are disseminated. That this rock was originally made up of pellets is evident in the remnants remaining of such shapes. Some of the finest of the grouped quartzes do not interlock, but lie in an isotropic matrix of the dirty green substance mentioned, and in such position they are accompanied by small spicules of actinolite and apparently by globulites of calcite. This greenish sub-isotropic substance is of secondary origin, but in some sections, already noted, it can hardly be distinguished from the older isotrope.

The original pellet structure of this rock would hardly be detected except by one who traces the pellet forms through the series of transformations from one extreme to the other of alteration.

No. 179—1709 ft. to 1717 ft. In this case, while the pellet forms are evident, they are altered most frequently to fine interlocking quartz, or to calcite and the secondary green matrix stuff, or to iron ore, quartz and the secondary green matrix stuff, or wholly to the secondary green matrix stuff, or more rarely almost wholly to calcite; yet calcite is more likely to transgress the limits of the pellets and to spread in large plages more widely. Besides the fine quartz that is in the pellets, a much coarser interlocking quartz surrounds and outlines the pellets.

No. 181—1726 ft. to 1732 ft. Calcite plays the most important and conspicuous role in this slide. It is in large crystals which are interlocked with almost an equal amount of secondary quartz and shows two periods of growth, as already mentioned of this mineral in other slides. It also exhibits a shadowy extinction, denoting disturbance and tortion. The borders of the older calcites are marked, sometimes, by a dark rim which seems in part to outline the original pellet shapes, apparently composed of very fine calcites. In other cases the borders of the larger calcites are composed of innumerable fine calcites that appear to have been either of secondary origin, or to have been separated from the main crystal by some frictional movement.

No. 184—1748 ft. to 1754 ft. Quartz and calcite about equally compose this section, the latter forming large plages which surround many quartzes, and having a shadowy extinction. There is a little of the secondary greenish isotrope embracing actinolite. On lowering the lower nicol and removing the upper, the outlines of the older calcites are seen to be expressed by the dark rims formed of the fine calcites. These fine calcites polarize only in part in unison with the larger crystal.

No. 187—1766 ft. to 1774 ft.. While this slide is in part composed of the primary matrix stuff, it is wholly fragmental, and really consists almost wholly of granular calcite. It does not at all represent the rock which was described megascopically.

No. 188—1774 ft. to 1779 ft. The description of No. 184 will apply very well to this slide, but the calcites are smaller and less numerous. Actinolite is more frequent and the pellet forms preserved.

No. 189—1779 ft. to 1787 ft. The description of No. 187 applies well to this slide.

No. 190—1787 ft. to 1794 ft. The fragmental structure of this rock is evident. The sizes of the original pellets can be seen although they are small and it is a dark rock. The differences in translucency and in the fineness of the secondary quartz grains, distributed all over the section in more or less rounded areas, show not only that the rock was composed of pellets, but that the alteration is such that only volcanic glass is known to undergo. Calcite is a large constituent in the alteration products, although its high double polarization colors can not always be distinctly seen. The original glass is so dark and the little calcites are so crowded that they impart to the grains which they permeate only the smallest amount of diffused and transmitted light, and this transmitted light appears mainly in small points. There is in the slide a little quartz, indeed some of the original pellets have been replaced almost exclusively by secondary, grouped, interlocking grains of quartz. Actinolite has been generated in some of the pellets.

In a second slide the calcite is abundant and evident.

No. 195—1828 ft. to 1832 ft. This rock is essentially a very fine-grained, dark limestone, the dark aspect being due to the dissemination of a debris which is opaque and formless and embraces the fine calcites as a loose and scant sponge, and in some places constitutes independent larger masses and patches in which still can be seen occasionally a few calcites. Actinolite spicules pierce both the calcite and this dark debris. This dark substance is not always opaque, but partly translucent and then it embraces still finer calcites and some quartz. There is also a little of the secondary isotropic substance already mentioned, and such areas are pierced by actinolite.

No. 199—1858 ft. to 1868 ft. The section is composed mainly of quartz, some of the grains being bipyramidal, and some of the others, much finer, giving square sections, these latter being embraced sometimes within other much larger interlocking quartzes, and extinguishing like bipyramidal crystals. The quartz is all diversified by varations in fineness characteristic of the pellet-structure. A small portion is fibrous and negatively elongated like chalcedony. Sometimes the original pellet, though now consisting essentially of secondary finely granular quartz, is clouded by a remnant of the secondary greenish-yellow isotrope, in which the quartzes seem to be as in a mesh. This isotropic matrix has all stages of distinctness and of translucency (with one nicol) from almost invisibility to dark, almost opaque but yellowish-green. Some of the original pellets now consist largely of this dark, green substance.

Some calcite and a very little actinolite, but no iron ore can be seen.

With the highest power and concentrated light this greenish-yellow substance, between crossed nicols shows a granular structure, some of the grains polarizing yellowish, these being about one half, and much of the remainder being apparently quartz, but they are too fine to be determined specifically.

No. 202—1883 ft. to 1892 ft. Quartz is the most abundant element, spread throughout in interlocking grains that exhibit the pellet-structure grouping and variation of size. Calcite perhaps comes next, and then iron ore, these two being closely associated, and the latter in lenticular and arrowhead shapes. These shapes are not due to the crystalline form of the ore but to the shape of some substance which it replaces, and are by no means the only forms that the iron ore shows, many of the grains being of very irregular shape. Sometimes the substance of one of these original lenticular grains is not wholly replaced, allowing the study of that portion that remains, sometimes a rim about the ore, and sometimes one or more elongated areas roughly embraced within the ore grain. Sometimes the associated substance is actinolite or some other amphibole, sometimes actinolite and calcite and sometimes it cannot be determined, but is nearly isotropic. In some cases it was a cotemporary and parallel growth with the iron ore. Actinolite is abundant in fine threads and spicules, occasionally in sheaf-like clusters. Calcite is chiefly in conspicuous plages, but also in granular aggregates too fine to show distinct polarization, and in irregular splashes in the quartz. There is no trace, so far as can be seen, of the isotropic green substance seen in many slides, but all the slide is crystallized, excepting a few stains of red oxide of iron.

No. 203—1892 ft. to 1901 ft. Irregular threads, masses and aggregates of iron ore lie in association with calcite and a sub-isotropic substance. Some of the iron ore masses are globular, and instead of being solid consist of a crust of iron ore with the interior filled with the sub-isotropic substance mentioned. In the slide is very little quartz, but the matrix of the ore is minutely granular calcite. What quartz there is is in the matrix. The structure and composition of the yellowish interior of the iron ore balls is interesting and important. In a high power it is resolved mostly into actinolite, which for the most part is in radiating stellar areas between which remain a number of small areas that are constantly nearly dark, rotated between crossed nicols. Still even these sub-isotropic areas appear to consist wholly of actinolite so crowded and crossed as to obstruct the passage of polarized light. In some cases there appears to be a remnant also of the isotropic secondary greenish substance that has been mentioned, containing fine dark inclusions. Widely distributed through the fine calcite matrix are also fine grains of black iron ore.

No. 206—1920 ft. to 1929 ft. Quartz, calcite, iron ore, and actinolite compose this slide, rather heterogeneously mingled. It is observable that the fine globular calcites when massed together exhibit sometimes a common darkening four times in a rotation showing a common orientation. This goes further, and shows a combination which gives the characteristic polarization over small areas, then over larger areas, exhibiting finally the perfect crystallization of calcite. The actinolite is in isolated bunches, as described in No. 203, but not so completely surrounded by rims of iron ore. These bunches, as well as the changes of grain of the quartz and the bunched disposition of the calcites are remnants of the original pellet structure of the rock.

No. 207—1929 ft. to 1939 ft. Same as No. 206, but consisting more largely of iron ore and showing generally a more complete and coarse crystallization.

No. 211—1966 ft. to 1975 ft. Variously granular quartz, interlocking, calcite, iron ore and a little actinolite.

No. 213—1984 ft. to 1992 ft. Very similar to No. 211, but the quartz distinctly shows the forms of the original pellets, being clouded by dark, dust-like particles which are probably of iron ore and by still finer irresolvable particles which seem only to impair the translucency of the quartz. There is a little calcite with perfect crystal outlines, and also some that has suffered crushing, presenting an imperfect and shadowy extinction.

No. 215—2001 ft. to 2008 ft. The slide consists very largely (almost entirely) of a loose sponge of iron ore, in the openings of which is calcite, which also seems to embrace the iron ore in the form of a reciprocal similar sponge. The slide contains almost no quartz. Rarely is seen a small area of the secondary green isotrope already mentioned, into which the calcite is idiomorphically projected—as seen conspicuously in Nos. 141 and 150 as well as in others.

No. 216—2008 ft. to 2014 ft. This section shows a rock composed of, mainly, exceedingly fine-grained calcite, but darkened by equally fine grains of an isotrope, which in some places forms a scant mesh for the calcites. It is essentially a dense limestone.

No. 218—2016 ft. to 2020 ft. There is a large proportion of this rock composed of a nearly glass-clear isotropic substance. This appears as sub-rounded grains, and as a matrix that encloses innumerable angular fine quartzes, also as irregular, much branched spreading masses. This isotrope not only surrounds the quartzes, but is apparently itself fragmental, as the bright Becke line sometimes separates it into smaller areas. In some places fine interlocked quartzes occupy the field, and in others perhaps the larger part appear only rounded detrital grains of quartz in the interstices of which are not

EXPLANATION OF PLATE I.

Fig. 1 (the upper figure) Specimen No. 1 (at 145 ft.) × about 75 diameters, in ordinary light, showing translucent and opaque glass grains, with quartz.

Fig. 2 (the lower figure) Specimen No. 1 (at 145 ft.) × about 25 diameters, between crossed nicols, showing the general prevalence of an isotropic fragmental substance.

PLATE I. Sections of the Mesabi Rocks

EXPLANATION OF PLATE II.

Fig. 1 (the upper figure) Specimen No. 130, at 1459 ft. × about 100 diameters. Showing a coarser condition of the same elements as seen in Plate 1, in ordinary light, but mainly of the isotropic substances. In the upper margin is a pebble of dark glass, and along the upper left margin of the pebble the glass is totally opaque and black. The main body portion of this figure shows a composite rock made up of fine fragments and shreds of dark glass mingled with angular quartzes, etc., indicating an earlier detrital accumulation. The light part of this figure is composed of translucent volcanic glass, in fragmental condition.

Fig. 2 (the lower figure) Specimen No. 130, at 1459 ft., × about 100 diameters, an average aspect of the slide, showing almost opaque glass in rounded fragments surrounded by translucent glass debris.

PLATE II. Section of the Mesabi Rocks.

EXPLANATION OF PLATE III.

Fig. 1 (the upper figure) Specimen No. 141, at 1502 ft. × about 25 diameters, parallel light, showing calcite crystals generated in the translucent and in the non-translucent glass, crossed by a vein of quartz.

Fig. 2 (the lower figure) Specimen No. 219, at depth of 2020 ft. × about 25 diameters, between crossed nicols. Showing a detrital quartzyte having an abundant matrix of basic volcanic glass, and some coarser rounded grains of the same.

PLATE III. Sections of the Mesabi Rocks

only secondary growths but also much of the isotrope mentioned and a little calcite. Some of the fine quartz is hardly distinguishable from opal, owing to a general darkness when crowded. Some square sections suggest fluorite.

No. 219—2020 ft. to 2027 ft. The rock is a granular detrital quartzyte, but contains a few grains of microcline and a few of rounded volcanic glass, as well as a uniform isotropic matrix which was originally volcanic ash or debris. The grains of the slide are all rounded or sub-rounded except those that fill the interstices, and these are so fine that they make an apparently uniform and homogeneous matrix, the high relief of which contrasts with the dead flatness of the quartz. This matrix is so abundant that the quartzes scarcely come into contact. In some places this matrix is differentiated so as to show a few minute spicules of actinolite and in general it is more or less devitrified. Its high refractive index indicates a basic glass. Plate III, Fig. 2.

No. 220—2027 ft. to 2035 ft. Same as the last but with less copious matrix.

No. 221—2035 ft. to 2040 ft. Same as the last but with a very copious matrix of volcanic ash which has developed some iron ore in fine grains, and many actinolites, also a little calcite and sphene—the last, however, perhaps being detrital and cotemporary with the quartzes. There is also a conspicuous tourmaline which is probably of detrital source.

No. 222—2040 ft. to 2049 ft. Quartzyte, having a scant matrix, in the interstices, of volcanic ash.

This being the lowest point reached by the drill, it appears that there must have been volcanic rock still older, and possibly iron ore at a lower level. Still it is not known that ore occurs at any place below this quartzyte.

This section also contains fragmental grains of tourmaline.

III. REMARKS ON THE FOREGOING SECTION.

1. Nature of the rocks and their alterations.
2. Relation to iron ore.

1. *Nature of the Rocks.* Although in the megascopic descriptions some of the samples were named basalt, yet no massive basalt was found in the microscopic examination. Instead was found compacted fragments of basaltic glass, which outwardly necessarily resemble massive basalt. These fragments were found to be of all shapes and degrees of fineness, some of them being microscopic pebbles, as they appeared under the microscope, and prevailingly having rounded contours, like detrital sand, giving a pellet structure to the rock. Along with these rounded basalt grains were others consisting of quartz, and in some specimens a considerable portion of the whole consisted of other kinds of sedimentary grains.

Near the bottom of the drill the sedimentary grains are coarser, and are more largely composed of rounded quartz. But the lowest specimen taken still contains a noticeable amount of translucent isotropic glass.

The whole section considered, it is a reasonable estimate to place the eruptive elements at over 50 per cent of the whole. Through large thicknesses of the rocks the volcanic element would reach 90 or 95 per cent of the whole.

Those sediments indicate a rapid supply of sedimentary basaltic grains extending from the bottom to the top of the Mesabi section. The most marked isotropic aspect is, perhaps, that found at the very top of the drill-section, when the rock was first struck by the drill.

There is but one exception to this general statement, viz: Rock found at the depth of 630 feet, which is apparently a dike, of strong soda characteristics, and which may be a crystalline derivative from the main mass. It is the writer's intention to further consider this point later.

It has been suggested that this isotropic substance is of the nature of a chemical colloidal deposit. It is the source of the iron ores and of the secondary quartz.

Against this suggestion the following objections arise at once:

1. It is constantly fragmental.

2. The fragmental constituents differ amongst themselves:—

(a) In translucency, some being nearly opaque and some quite opaque.

(b) In their inherent color, although in immediate contact, some being brown and some greenish.

(c) In the number and sizes of their globular inclusions.

(d) In the degree of devitrification.

(e) In the size of the fragmental grains, some being from 50 to 100 times the size of others.

3. The fragments of the isotrope are associated with other detrital materials, such as quartz (chiefly) and to some extent apparently with muscovite and sphene.

4. The fineness of the constituent grains varies exactly like the variation of fineness of a sedimentary rock. It is fine as a powder and as course as fine pebbles, the latter being evident megascopically.

5. It has in some cases manifestly suffered two epochs of fragmental accumulation, some of the larger pieces being themselves plainly composite in structure and in character. Such prolonged, and interrupted, accumulation as an identical oceanic colloid would be very unlikely and almost impossible.

6. No such compound oceanic colloidal sediment is known. Colloids are likely to be simple and homogeneous.

7. Such a colloidal accumulation would not maintain a constant fragmental structure through such a thickness of strata.

8. But in many places it would be massive and destitute of other sedimentary materials. No such massive condition has been found.

9. An assumed colloid of iron oxide and silica could not give the alteration products common in this rock, such as calcite and actinolite, which are habitual.

10. On the other hand, a greenish secondary colloid (or at least a nearly isotropic substance) is one of the products of alteration.

Alterations. Throughout the most of the drill section this isotropic substance is mainly unaltered from the condition in which it was deposited, enclosing only such ultra fine globulites as were in it prior to deposition. Alteration begins to appear on approaching the horizon of the iron ore bodies, and is most pronounced at that interval in the strata where it is known that the iron ores occur.

Quartz probably was the first mineral to form from alteration, since it appears in an interlocking relation with the apparently unaltered glass. Still such new quartz may have had other source.

Calcite is the most pronounced product of alteration, appearing not infrequently in form of perfect crystals, as well as in grouped incipient globular forms whose nature at first was not detected. Quartz also accompanies the generation of this calcite, and occasionally in form of perfect crystals which are bipyramidal.

A *secondary green isotrope* is also common at about this stage and continues to near the bottom of the drill section. This is the well-known glauconite of Spurr. It serves as a matrix for both calcite and quartz, as well as for actinolite and magnetite.

Actinolite appears abundantly before the abundant appearance of iron ore, but they are close associates as to date of generation. As the change progresses to this stage, quartz becomes more and more abundant, filling almost completely most of the pellet-shaped original grains of glass, but still more or less accompanied by actinolite.

Magnetite, or what may here be taken for magnetite, shares with quartz and actinolite the occupancy of the areas of the original pellets. Some of the original pellets are also completely filled, sometimes by a single mineral. Thus some are composed of fine interlocking granular quartz, as in jaspilyte, some of the secondary green isotrope, some of iron ore, and some of calcite, the last being quite rare.

2. *Relation to the Ore.* The secondary green isotrope, or glauconite has nothing to do with the origin of the ore. It is a product of chemical alteration of the basaltic glass of the original rock, as much as is the iron ore or the quartz.

The agency of igneous rock in the localization of ores is being more and more recognized, and this seems to be one of the most remarkable instances of such agency. If, however, the ore originated from a change in igneous rock, the question arises—why was that change not continued throughout the whole mass? Why was it confined essentially to strata near the bottom of the series? The answer to this requires the recognition of conditions, cotemporary with the deposition, which were different at the site of this drill hole, at the bottom of the series from those that marked the strata near the top. As the writer contemplates another chapter in this investigation, he will forego further discussion at this time.

THE PROPER DETONATION OF HIGH EXPLOSIVES

BY CHARLES S. HURTER, DULUTH, MINN.

In compiling this article the writer has drawn his information from several well known authorities. The matter is so interwoven that it is practically impossible to give each man credit for the exact amount of reading matter obtained. In order of the information obtained, they are as follows: Berthelot, Guttman, DeKalb, reports of His Majesties Inspectors of Explosives and Walke.

Guttman divides explosives into two classes, namely Low Explosives and High Explosives. Low explosives are those which can be made to develop their full force by direct means, such as simple ignition. The principal explosive in this class is blasting powder. Practically all the sporting and ordinance powders belong to the Low Explosive Class. High Explosives are that class of explosives that require an intermediate agent, such as a fulminate detonator, to cause them to develop their full explosive force.

There is one exception to this method of classifying explosives. Fulminate of mercury, and mixtures with this as a base, such as are commonly used in blasting caps and electric fuzes or detonators, together with nitrogen iodide, silver oxallate, nitrogen sulphide and other explosive freaks have the action of high explosives but develop their full force upon simple ignition. A large number of authorities place them in a third class called Fulminating Explosives.

The action of blasting powder on exploding is that of a very rapid process of oxidation. As a contrast to this, the action of high explosives consists principally of a simple dissociation of compounds, followed by an oxidizing action, such as the reaction between the oxygen excess present when nitroglycerine is detonated and the compounds placed in the dope of dynamite to take up this excess and secure the so-called "balance of formula."

Another classification shows low explosives to be mechanical mixtures, such as blasting powder; while high explosives can be regarded as chemical compounds.

In the low explosive class, the action takes place by means of the reaction of the particles composing the different substances in the mixture upon each other, the explosion being propogated from one group of such particles to the next and so on throughout the entire mass. An explosion so produced is necessarily relatively slow. A shock, unless of such extreme violence as to produce friction, will not explode blasting powder.

The case is different with high explosives. Here the elements that make up the explosive compounds are combined into definite molecules of uniform composition, held together by a relatively feeble chemical attraction. A shock will overcome the bonds which hold these elements together, upon which they are free at once to react upon each other, producing gases at a high temperature, the result being an explosive effect. An explosive wave is thus generated, which is continued throughout the entire mass. If the shock be sufficiently violent, the energy of the initial wave will be reproduced throughout the entire mass. Thus perfect combustion is accomplished in an infinitely small space of time, and an effect of particular violence is obtained which has been called "detonation." The subject of detonation will be discussed at considerable length later on.

HIGH EXPLOSIVES.

The high explosives or dynamites used for blasting in the United States are divided into three classes commonly known as Straight Dynamite, Ammonia Dynamite and Gelatin.

The first dynamite that appeared on the market was composed of 75 per cent nitroglycerine and 25 per cent of an infusorial earth called kieselguhr. The kieselguhr being an inactive substance consumes some of the strength of the nitroglycerine and detracts from its sensitiveness. The result is that the 75 per cent kieselguhr dynamite is only about as strong as the American 40 per cent and kieselguhr dynamite containing less than 40 per cent of nitroglycerine cannot be exploded by ordinary means.

Another of the earliest absorbants used for nitroglycerine was sawdust. It was from this that the American Dynamites of the present day were evolved. Theoretically, when nitroglycerine is detonated, five per cent of the gases given off is free oxygen. The dope of the dynamite is made up largely of wood pulp and either sodium or potassium nitrate in proportions to make a complete balance of the chemical reactions which take place on detonation. Dynamite made in this manner may contain as low as 12½ per cent or as high as 75 per cent of nitroglycerine, and constitutes what are known at the present time as straight dynamites.

The series of straight dynamites constitute also the standard series against which all other explosives are compared, and contain or should contain the actual proportion of nitroglycerine that is given as their "percentage strength."

The characteristics of the straight dynamites are their very quick and shattering action. This quickness increases with their strength. The water resisting qualities of the straight dynamite are better in the higher than the lower grades. The fumes from the straight dynamites are the poorest of the three classes of dynamite, the lower grades giving off less deleterious gases than the high. The straight dynamites are all very easily ignited by flame or sparks such as might issue from the sides of defective or the cheaper grades of fuse. Therefore, considerable care must be used in the making and placing of primers when using straight dynamite for blasting.

By replacing all of the nitrate of soda or potash, as the case may be, and part of the nitroglycerine with nitrate of ammonia, a series of explosives, having strengths similar to those of the straight dynamites, obtained are, called Ammonia dynamites. This class of explosives has distinguishing characteristics that make them very valuable for certain classes of work.

As the ammonia dynamites contain less nitroglycerine than the corresponding grades of straight dynamite, they have a somewhat slower action. The fumes are very much superior to those of the straight dynamites. They are the most difficult of any of the ordinary high explosives to ignite. It is practically an impossibility to ignite ammonia dynamite from the side spit of any kind of fuse or even if the end of a length of fuse is inserted into the cartridge without a blasting cap. The water resisting qualities of ammonia dynamite are not as good as those of the straight dynamites but this difference can be almost entirely overcome by dipping the cartridges in melted paraffine after filling. The sensitiveness of the ammonia dynamites is less than that of the straight dynamites and therefore nothing less than a No. 6 detonator should be used to explode them.

In the course of the experiments made by Alfred Nobel with explosive compounds, he found that he could dissolve some of the lower grades of guncotton in nitroglycerine forming water proof explosive jelly that was slightly stronger than the pure nitroglycerine itself. This jelly is the base of the present gelatins or gelatin dynamites. The gelatins are very slow in their action when detonated by the ordinary No. 6 blasting caps but when exploded by an extremely severe shock such as when a primer is made of high grade straight dynamite or the pure blasting gelatin the action is quicker than the corresponding grades of straight dynamite.

The gelatins are the densest of the high explosives which fact makes them very valuable for tight blasting where a concentrated charge is desired at the bottom of the holes. The fumes are superior to those from both the straight and and ammonia dynamites. Being very nearly water proof in the lower and perfectly waterproof in the higher grades, the gelatins are best adapted for use in extremely wet work and submarine blasting.

During the last four years a series of low freezing nitroglycerine dynamites have been placed on the market and have met with great favor in certain sections of the country.

Ordinary nitroglycerine dynamite freezes at temperatures between 45 and 50 degrees Fahrenheit. A number of the nitro substitution organic compounds have the effect of lowering the freezing point of nitroglycerine in the same manner that common salt lowers the freezing point of water.

By the use of some of these compounds, it has been possible to make straight and ammonia dynamites that will not freeze at temperatures above 32 degrees Fahrenheit. The freezing point of these explosives is variable, but it is a well known fact that they will not freeze in places where ice will not form. Some of them have been known to have remained at temperatures as low as 5 and 10 degrees Fahrenheit for days without freezing. Others froze under these conditions, but it is a well known fact that as long as water will not freeze, they are sure to remain soft and in good condition.

These explosives of the ammonia class have become very popular in a large number of the mines of Northern Michigan and Minnesota, where they can be taken below ground frozen solid on the coldest day in winter, and after remaining over night in a place where water will not freeze, they will be thawed out perfectly.

By using these explosives the trouble and delay necessary to thaw ordinary nitroglycerine explosives in some of the mines whose temperature is low enough to freeze nitroglycerine is entirely obviated. This gives the miners more time to attend to their regular duties and removes the temptation to follow the dangerous practice of using frozen dynamite for the blasting of the holes drilled, if not enough thawed powder is on hand.

The fumes from the straight grades of low freezing dynamites are so poor that their use underground should not be attempted except in places where the ventilation is very good.

DETONATORS.

In practice detonation is accomplished by means of an intermediate agent that will produce both shock and heat. The relative amounts of shock and heat depend on the composition of the detonator charge.

Fulminate of mercury is the compound which forms the basis of all detonator charges. According to Berthelot, this is the most powerful detonator. That is to say, the shock from fulminate of mercury is quicker and more violent than that of any other substance used for producing detonation. This is explained by the suddenness of its decomposition, together with the extraordinary magnitude of the pressure which it would develop when detonating in its own volume. This is given as 2,600 atmospheres or 38,220 pounds per square inch.

In regard to the phenomenon of detonation, the action which takes place depends more or less on the strength of the initial pressures, on the suddenness of their development and the relative stability of the compounds used to make up the explosive which in turn regulate the ease of the communication of the shock to the rest of the mass. That is to say, the action which takes place depends on the conditions which regulate the energy transformed into heat in a given time on the first layers of the explosive substance reached by the shock.

The quantity of energy thus transformed depends, therefore, both on the suddenness of the shock and the amount of work it is capable of performing.

This gives us two conditions which vary with each explosive substance. Thus the most suitable priming mixtures and compounds are not always those in which the explosion is most instantaneous. For instance, nitrogen chloride and nitrogen iodide, which are much quicker in their explosive action are not as suitable primers as fulminate of mercury. The chemical reaction that takes place on the detonation of fulminate of mercury, is expressed as follows:

$$Hg\ C_2\ N_2\ O_2 = 2\ CO + N_2 + Hg$$

According to this equation only carbon monoxide, nitrogen and mercury vapor are formed. One, only of these is a compound, and it is stable and not susceptible of dissociation. This fact accounts for the suddenness of the explosion. Moreover the total heat of decomposition is disengaged at once, and the gases are produced without the occurrence during cooling of any progressive recombination that would tend to moderate their expansion and diminish the violence of the first shock. The condensation of mercury vapor can be disregarded as this only takes place at temperatures below 680 degrees Fahrenheit.

Mixtures of fulminate of mercury with other compounds are made with the object of increasing the amount of heat liberated and thus the pressure of the gases are formed. The compound most commonly used for this purpose is chlorate of potash. The decomposition of chlorate of potash into potassium chloride, and oxygen liberates a certain amount of heat and the conversion of carbon monoxide into carbon dioxide generates a great deal of heat. On the other hand this oxidation being a secondary reaction the shock is not quite so sharp, but as detonation can be caused by heat as well as by shock, it is possible to use mixtures where the great gain in heat more than counter-balances any deadening of the shock.

The chemical reaction involving fulminte of mercury and chlorate of potash to produce the complete combustion of their products, is expressed according to the following equation:

$$\underset{852.12}{3Hg\ C_2\ N_2\ O_2} + \underset{245.2}{2\ KCL\ O_3} = 6\ CO_2 + 3\ Hg + 2KCL$$

At the detonation temperature of fulminate of mercury the oxides of mercury cannot exist.

According to this reaction 245.2 parts by weight of chlorate of potash must be mixed with 852.12 parts of fulminate of mercury to bring about complete combustion. Roughly this proportion can be expressed as 2 parts of chlorate to 7 parts of fulminate. The mixtures in use vary from 80% fulminate and 20 per cent potassium chlorate to 95 per cent fulminate and 5 per cent of chlorate of potash, the idea being to get a mixture in which the heat developed will give the greatest assistance in producing detonation without deadening the initial shock of the fulminate.

SENSITIVENESS TO DETONATION.

The sensitiveness of explosive substances to detonation depends on the relative stability of the ingredients, the temperature of the explosive and the modes of propagation of the explosive reactions. One substance may be sensitive to the slightest rise in temperature, another to sudden pressure, another to shock and still another detonates with the least friction. Thus, for example, silver oxallate detonates at about 266 degrees Fahrenheit, nitrogen sulphide at about 405 degrees, and fulminate of mercury at about 374 degrees. Nevertheless, fulminate of mercury is more sensitive to friction than either nitrogen sulphide or oxallate of silver. Therefore, it can be said that special properties, depending on the chemical structure of each substance, particularly in solids, favor decomposition under given circumstances.

There are also some general conditions which affect the sensitiveness of explosives to detonation. The sensitiveness of any explosive substance increases with the initial temperature at which the explosive reaction begins; or in other words the sensitiveness of any explosive substance to detonation becomes greater as the temperature at which the body commences to decompose spontaneously is approached. The explanation of this is that the best liberated by the explosive reaction proper, undergoes less loss by radiation, and as a result, at the beginning of the explosive reaction a greater weight of the non-decomposed substance is raised to the desired temperature. These facts, especially that in regard to the temperature of the explosives, can be considered as some of the primary causes of accidents in the thawing of nitroglycerine explosives when they are allowed to become overheated by careless or the use of improper methods of thawing.

The sensitiveness to detonation of an explosive substance will be rendered still greater if this temperature limit is exceeded; that is, if conditions prevail under which a slow decomposition may be transformed by the least shock or additional heating, into a rapid decomposition. A substance taken at a point near or above this limit may be considered to be in a state of chemical tension.

Sensitiveness to detonation also depends on the quantity of heat liberated by decomposition. That is to say, that all other things being equal, the explosive substance that liberates the most heat is most sensitive to detonation. To go into detail one can easily conceive that with an explosive that generates a large amount of heat, that if a small portion of this is brought to the temperature of detonation, it will communicate the explosive reaction throughout the entire mass much more quickly and completely than would be the case of an explosive that liberates a small amount of heat.

The same quantity of heat will produce different effects on the same weight of matter, according to the heat conductivity of this matter. For instance, chlorate of potash, whose specific heat is 0.202, is a better conductor of heat than nitrate of potash whose specific heat is 0.239. Thus chlorate powders should be and are more sensitive than nitrate powders. This together with the lower temperature of decomposition of potassium chlorate and the fact that chlorate of potash by itself gives off oxygen and liberates heat at the same time, renders chlorate powders extremely dangerous, they being liable to spontaneous explosion at any time.

The structure of an explosive also has an effect on its sensitiveness. In the explosives containing nitro-glycerine in a liquid form the principle of the incompressibility of liquids plays a very important part in their sensitiveness. The fact that liquids cannot be compressed and that under the quick severe shock of fulminate of mercury the inertia of liquids causes them to act more like solids, enables the shock producing the detonation to be more easily communicated throughout the entire mass. The larger the percentage of liquid nitroglycerine the better will be the manner in which the shock is propagated and thus the greater the sensitiveness.

On the other hand blasting gelatin which is a rubber like mass made by dissolving one of the lower grades of guncotton in nitroglycerine, has a certain amount of give and can be compressed. In order to overcome this a stronger detonator must be used to explode blasting gelatin and the other gelatins than is the case with the straight dynamites which contain liquid nitroglycerine. In fact this deadening action due to the compressibility of gelatin is such that it is impossible to make a reliable gelatin of less than 35 per cent strength.

The gelatins show a very interesting combination of explosive substances in order to increase the heat and consequently the strength of the explosive substances used in their manufacture. Roux and Serran give the relative strength as follows: Nitroglycerine 10.0. Compressed guncotton 6. 5. In the gases from detonated nitroglycerine there is theoretically 5.3 per cent free oxygen. In the gases from detonated guncotton, there is 49.3 per cent of carbon monoxide. (CO) By balancing the oxygen deficiency of the guncotton by means of the oxygen excess in the nitroglycerine, the extra heat units, gained by producing complete combustion, make the resulting blasting gelatin a little stronger than the pure nitroglycerine.

In the ammonia dynamites the sensitiveness is also lessened because of the reduction of the liquid nitroglycerine contents in order to allow the use of nitrate of ammonia. Hence nothing less than a No. 6 detonator should be used to explode either gelatin or ammonia dynamite. In the European countries this rule is made compulsory by law. The European No. 6 detonator contains 1 gram (15.4 grains) of a mixture made up of 80 per cent fulminate of mercury and 20 per cent chlorate of potash.

Compressed guncotton is less compact than nitroglycerine owing to its structure. The presence of spaces however minute, causes the pressure due to shock to become sensibly attenuated. Guncotton as it contains these spaces is therefore, more difficult to explode than nitroglycerine. Nitroglycerine is exploded by the fall of a similar weight from a given height, by the use of a primer charged with guncotton, or a smaller weight of fulminate priming; whereas guncotton does not explode under the influence of nitroglycerine and requires a much stronger fulminate detonator to explode it.

This principle applies to the high explosives made up entirely of solid ingredients such as those with a base of either guncotton or nitro starch. The spaces between the particles of these powders act as cushions and prevent the shock of detonation from being communicated through them as easily as in even the gelatins, the straight or ammonia dynamites and therefore with this kind of explosives nothing less than a No. 7 or No. 8 detonater should be used. This class constitutes the bulk of non-freezing high explosives on the market at the present time.

Fifteen to twenty per cent of water can be added to cellulose dynamite, rendering it insensible to the shock of a rifle ball, without depriving it of the property of being exploded by means of a strong blasting cap. When dynamite is in this condition nitroglycerine is exuded at the slightest pressure. Dynamite containing water is very greatly weakened as part of the heat of detonation, depending directly on the proportion of water mixed with the dynamite is lost by the conversion of this water into vapor. This consumption of heat means a reduced expansion of gases and consequently a decrease in explosive strength.

Nitroglycerine is less explosive under the influence of a priming of fulminate of mercury, if it has been ignited by some other means before the explosion of the fulminate. The previous burning of the nitroglycerine produces a certain void between the two, which prevents the fulminate from doing its work properly. The absence of immediate contact between the dynamite contained in the cartridges and the priming of fulminate is prejudicial for the same reason, the shock being partly deadened by the interposed air.

The sensitiveness to the action of fulminate is greater in dynamite containing liquid nitroglycerine than in that containing frozen nitroglycerine. When nitroglycerine solidifies, like a large number of compounds, it crystallizes. According to the laws of crystallization, when a substance crystallizes it tends to exclude all foreign matter. This principle is made use of in the Pattison Process for refining lead bullion, in the purifying of common salt and quite a large number of other compounds. Thus when dynamite freezes, the nitroglycerine tends to separate to a small extent from the dope. To this absence of homogeneity, Berthelot lays the reason for the insensitiveness of frozen dynamite. If dynamite is thawed slowly at a temperature not exceeding 80 to 85 degrees Fahrenheit the nitroglycerine will be re-absorbed in the dope as perfectly as it was originally.

DETONATION.

In the discussion of the detonation of explosives from a technical standpoint, the chemical reactions, etc., that take place when explosives are completely and incompletely detonated, grade into one another in such a manner that it is hardly possible to treat these subjects entirely under separate headings.

Berthelot claims that there is no line of demarcation between combustion or explosion of the blasting powder order and detonation but that they represent the two limits of a wide range of explosive phenomena.

When an explosive substance is detonated in its own volume, the maximum of temperature and pressure, and consequently the maximum speed of the chemical reactions involved, is attained; that is, the total heat possible to develop in the reaction is obtained at the instant that the energy of the explosion is exerted on the surrounding medium.

DeKalb says that in no case is detonation absolutely perfect under ordinary conditions, but this perfection is approached more closely according to the concentration of the explosive impulse due to good confinement.

Some experiments made by the Western Australian Government Commission and described in the English "Blue Book" of 1905, showed that the tamping of charges has a very marked effect on the proper detonation of the explosive used. When boreholes are tamped carelessly or when no tamping is used, the lack of confinement apparently causes a small part of the explosive to be detonated incompletely and consequently more offensive fumes are given off than when the charge is tamped properly.

As already mentioned, detonation is produced commonly in practice by means of a very sudden shock, in which heat plays an important additional but secondary effect. The gases formed at the point where the shock is first produced have not time to become displaced, so to speak, and they immediately communicate their energy to the parts of the explosive in immediate contact. The action is thus propagated throughout the entire mass with a sort of regularity producing in it a veritable explosive wave.

As a contrast to this, progressive combustion transmits itself step by step throughout the mass under conditions in which the cooling due to conductivity by contact with the enclosing medium, lowers the temperature sometimes to the lowest degree compatible with the continuance of the reaction.

In regard to the effects of shock on nitroglycerine, it is sufficient to admit that the pressures, resulting from the shock administered on the surface of nitroglycerine, are too sudden in their action to distribute themselves uniformly throughout the entire mass. Consequently the transformation of energy into heat takes place more especially in the first layers reached by the shock. If this shock be of sufficient violence, the first layers may be suddenly raised to a temperature about 392 degrees Fahrenheit, which will cause them to be decomposed immediately, producing a great quantity of gases at a high temperature. This production of gas, in its turn, is so sudden that the body struck has not time to be displaced and the sudden expansion of the gases from the explosion produces a second shock, possibly more violent than the first on the layers of explosive situated below.

The energy of this new shock is transformed into heat in the layers which it first reaches, which causes their explosion. This alternation between a shock developing an energy which becomes charged into heat and a production of heat which raises the temperature of the heated layers up to a degree of a new explosion, capable of reproducing a shock, transmits the reaction throughout the entire mass of the explosive.

Thus the propagation of the explosive action takes place by virtue of phenomena comparable to those which give rise to a sound wave. That is to say, a true explosive wave is produced, which travels with a speed incomparably greater than that of simple inflammation effected under conditions which allow the gases to expand freely as they are produced.

This explosive wave travels at a greater speed and to greater distance in cartridges of large diameter up to a certain limit. One and three-quarters inches appears to be the diameter beyond which the ease of detonation of dynamite is no longer sensibly increased. With cartridges of smaller diameter it is possible to decrease the size to a point where the explosive can no longer be propagated throughout the charge. As the ammonia dynamites and gelatin came into favor, supplanting the straight dynamites, it became necessary to abandon the manufacture of explosives having a cartridge diameter of less than 7/8 of one inch. There are quite a few of the dry ingredient high explosives that cannot be used in cartridges having diameters of less than 1 1/4 or 1 1/2 due to their relative insensitiveness.

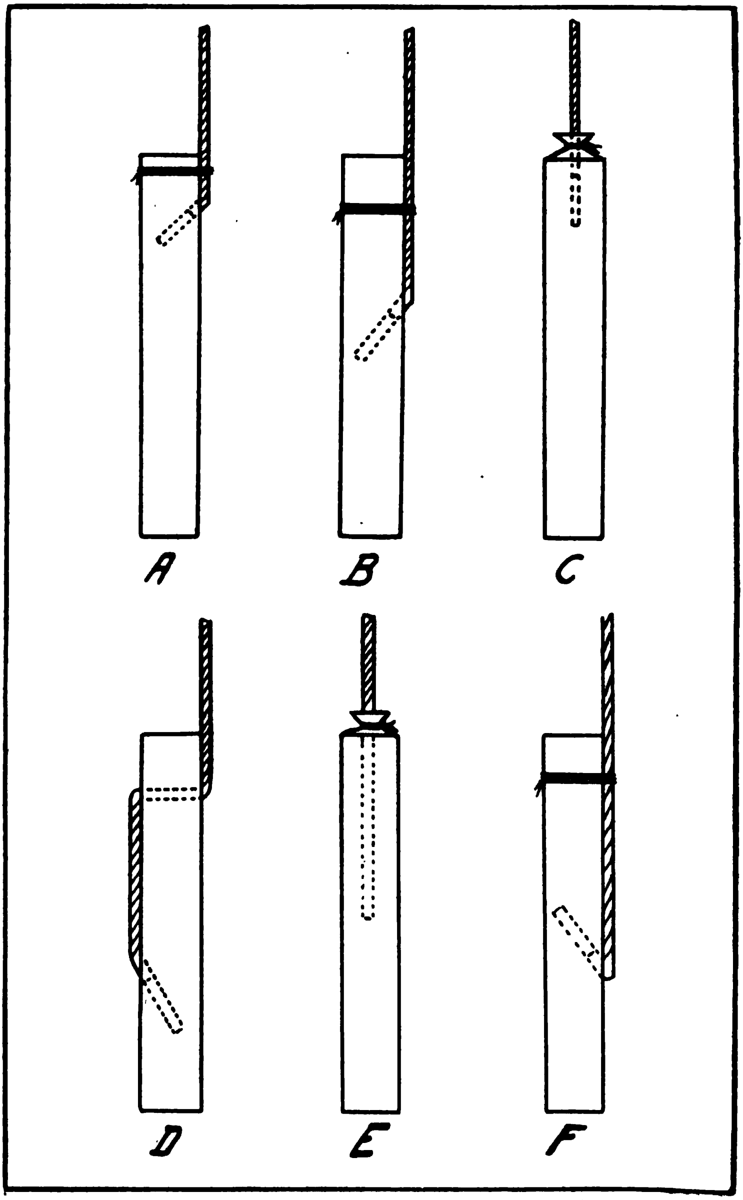
The reaction induced by a given shock in an explosive substance is propagated with a rapidity which depends on the intensity of this shock, because the energy of the first shock transformed into heat determines the intensity of the first explosion, and consequently the intensity of the entire series of consecutive effects.

The intensity of the first shock may vary considerably according to the mode in which it is produced. It follows then that the explosion of a solid or liquid mass may be developed according to an infinite number of different reactions, each of which is determined by the original impulse. The more violent the initial shock the more sudden will be the induced decomposition, and the greater the pressure generated during the entire course of the decomposition. One single explosive may, therefore, give rise to the most diverse effects according to the method of ignition. These facts shows the great importance of using strong detonators in practice. In fact Bichel strongly advises a large excess of fulminate in all detonators in order to overcome any bad effects due to possible moisture in the fulminate, and the possibility of the exploder becoming displaced in the primer. Also enough fulminate should be employed to insure the explosion of other cartridges than the primer, even if there should be small spaces between them.

In regard to the making of primers, the accompanying sketch shows several methods that' are in fairly common use. Those marked A, B, and C, are considered to be good practice, as the blasting caps are not buried deeply in the powder and there is a minimum amount of fuse in actual contact with the explosive.

In methods "A" and "B" the blasting cap is inserted in the side of the cartridge and pointed diagonally downward. The fuse being tied firmly to the cartridge. These methods are about as safe as any for loading as there is a small amount of dynamite that acts as a cushion between the tamping stick and the blasting cap. Method "B" allows a little firmer tying of the fuse than Method "A".

Method "C" is the one recommended for wet work in par-



Illustrations of Methods of Fastening the Exploders to the Dynamite.

ticular and for holes where the cartridges fit tight enough to crowd out the fuse. This style of primer takes longer to make than the others but with care and the application of a little grease, this primer should be able to stand water from 15 minutes to half an hour and is especially recommended for wet work.

One of the greatest difficulties experienced in the manufacture of safety fuse is to make a fuse that does not spit fire from its sides while burning. This is the cause of most of the burnt charges when the primers are made or placed so that considerable length of fuse is in contact with the explosive. The methods of making primers shown in the sketch at D, E and F, are considered bad practice by all authorities on explosives.

On the other hand the method of making primers as illustrated by "D" where the fuse is laced through the cartridge is no doubt the most common method in use.

The danger of trouble from the improper making of primers depends a great deal on the kind of explosive and the quality of fuse used. Methods "D," "E" and "F" are more likely to cause trouble with straight dynamites than with gelatins and more liable to ignite gelatins than ammonia dynamites. Then again the higher quality of fuse used, the less danger there is of igniting the charge.

Methods "D" and "E" should never be used with straight dynamites. With gelatins they are fairly safe provided triple tape or a very high grade of gutta percha fuse is used. With ammonia dynamites they are perfectly safe as it is impossible to ignite ammonia dynamite by the spit from any ordinary fuse.

Method "F" is to be avoided at all times as the sharp bend is liable to open the fuse so that water if present will cause a misfire. Also a sharp bend like this is liable to break the powder train also causing misfire. Also fire spitting from the opened fuse might ignite the charge below the cap and form a gaseous cushion that would prevent the cap from detonating the explosive. Sharp bends in the fuse are always to be avoided in making primers or in the loading of the holes.

In making primers great care should be taken that no part of the blasting cap projects from the outside of the cartridge. A large number of bad accidents have occurred due to the scraping of the blasting cap in an improperly made primer on the sides of the bore hole.

The Western Australian Commission, made a large number of experiments with straight dynamite. They state that a very great deal of trouble in regard to burning powder and bad fumes is caused simply by burying blasting caps too deeply in the priming cartridges.

The definition of safety fuse according to the English "Explosives Act of 1875" is as follows:

"The term 'Safety Fuse' means a fuse for blasting which burns and does not explode, and which does not contain its own means of ignition and which is of such strength and construction and contains an explosive of such quantity that the burning of such fuse will not communicate laterally with other like fuses."

In connection with this it is easy to conceive that while a fuse may spit fire through its covering with an intensity that will not ignite a similar fuse placed beside it, this fire might easily ignite any powder with which it may be in contact.

With electric fuzes the exploder may be placed either the end or side of a cartridge. Care should be taken not to bend the wires sharply in any direction, owing to the danger of breaking the insulation, causing grounds, short circuits and consequently misfires. The wires should be bound firmly to the cartridge by means of string, so that the electric fuze will not be displaced in loading or tamping. A great deal of trouble with misfires has been caused by taking hitches about the priming cartridges with the lead wires of an electric fuze or by bending them at sharp angles.

When blasts are fired by means of blasting caps and fuse, there is quite a little controversy in some sections of the country in regard to the proper position in the charge for the primer. As far as the actual execution is concerned the position of the primer cuts no figure whatsoever. On the other hand the position of the primer is governed almost entirely in the kind of explosive and the quality of fuse used.

With the straight dynamites owing to the great danger of igniting them, the primer should always be placed at the top of the charge. With the gelatins the primer can be placed anywhere with small danger of ignition provided a very high quality of fuse is used. With the ammonia dynamite it can be placed anywhere in the charge.

The breaking qualities of the ground occasionally determine the placing of the primers. In the country east of the Rocky Mountains the common rule is to place the primer at the top of the charge, then leave enough room on top of the tamping to allow for the coiling of the excess of fuse.

In the western states the general rule is to place the primer either at the bottom of the hole or just above the bottom cartridge. The miners in that section of the country state that if they should place the primer at the top of the charge the first holes would almost invariably blow the collars from some of the others cutting off the fuse, causing misfires and spoiling the round. By placing the primers at the bottom of the holes the fuses are all burning at a safe distance inside the collars when the first charges explode. The explosive most commonly used in that section of the country is gelatin and to lower the possibility of burnt charges to the greatest extent, nothing but the highest quality of gutta percha fuse is used. In regard to the priming of large charges it might be well to mention that Monro says that it is essential to observe that explosive material does not detonate, because it transmits the explosive wave, but on the contrary, because it arrests it. This means that a certain amount of the force of the original impulse is consumed as the explosion progresses, by breaking the bonds that hold the explosive compounds together. The amount of energy lost depends on the stability of the explosive compounds, the ease with which the explosive wave is transmitted and the presence of any interstices between the particles of the explosive substance. The rate of propagation of an explosive wave in a given substance increases with the density of loading.

In the blasting of deep holes where the charges are of considerable length, the weakening of the explosive wave can sometimes be noticed by the failure of the charges to break bottom cleanly. In order to keep the explosive wave at a maximum, the common practice in deep holes is to imbed strong blasting caps in the charge at intervals of not over five feet. These caps serve the purpose of bringing the energy of the explosive wave up to its maximum as fast as they are detonated. In deep holes it is best to have more than one detonator that can be fired as an extra precaution against misfires. This can be considered in the nature of insurance against loss due to misfires.

INCOMPLETE DETONATION.

According to the method employed for ignition, dynamite may be quietly decomposed without ignition; or it may burn briskly or, again, give rise to an explosion properly so-called, either moderate or capable of dislocating rocks or even locally crushing them, and producing the most violent effects.

Good dynamite undergoes practically no change when submitted to a temperature of 212 degrees Fahrenheit for one hour. Heated rapidly it takes fire at 428 degrees the same as nitroglycerine. If ignited it burns slowly without exploding, but if enclosed in a space with resisting walls, it explodes under the influence of heating. The same thing takes place sometimes in the inflammation of a large amount of unconfined dynamite, owing to the progressive heating of the interior parts, which brings the entire mass to the temperature of spontaneous ignition.

As already mentioned, Berthelot states that combustion and detonation represent the two extreme limits of an almost infinite number of explosive reactions. Between these two limits an entire series of intermediate reactions are observed. The unlimited number of these reactions is demonstrated by the effects of the various methods of inflaming dynamite. This can also be shown by the influence of sufficiently strong tamping which can convert a simple inflammation into a true detonation.

This variety of phenomena is due to two orders of causes, one being mechanical and the other more particularly chemical.

From a mechanical point of view it is conceivable that between the two limits of progressive combustion and detonation, intermediate modes of decomposition may be produced, according to circumstances. That is, when a combustion takes place, the local conditions surrounding the explosive substance, such as confinement, etc., have a direct influence on the quickness with which this combustion may be changed into a true detonation.

The chemical phenomena also may vary according to the conditions under which the reaction may be brought about. In the detonation of explosive compounds it is essential that complete combustion should take place. This does not necessarily occur in slow inflammation, effected at low temperatures, in which incomplete reactions may at first take place. Thus when dynamites and other explosive compounds, which have a complete "balance of formula," are burned or incompletely detonated, the oxides of nitrogen and carbon monoxide are given off in amounts which vary according to the heat developed by the reaction or reactions involved. In the proper detonation of these same explosives the gases would contain only nitrogen and carbon dioxide.

The following table is taken from the abstract of the report of the Western Australian Commission given in the English "Blue Book" of the year 1905:

Explosive—	CO_2	CO	N_2	O_2	H_2S	NO	H_2	CH_4
Nitroglycerine Exploded	63.2		31.5	5.3				

Nitroglycerine Burnt	12.7	35.9	1.3			48.2	1.6	0.3
Blasting Gelatin	68.5		31.5					
Gelignite	60.0		33.4	6.6				
Nitro Cotton Exploded	*21.7	49.3	16.3				12.7	
Nitro Cotton Burnt	*18.4	41.9	5.8			24.7	7.9	1.3
Blasting Powder	32.15	33.75	19.03		7.1		5.24	2.73

*Berthelot.

Gelignite (Weiskopf)

Nitroglycerine	63.4
Nitrocotton	12.8
Sodium Nitrate	14.2
Cellulose	9.6
	100.0

Gelignite (Guttmann)

Nitroglycerine	62.50
Nitrocotton	2.50
Sodium Nitrate	26.25
Wood Pulp	8.40
Soda	0.35
	100.00

In regard to the gases from Gelignite, the 6.6 per cent of oxygen represents the oxygen excess in all the high explosives formulae to take up the paper and paraffine of the cartridge. Thus if the paper is taken from the cartridges before loading part of their strength is lost. Also this oxygen will, under those circumstances, be liberated as nitric oxide (No) which is poisonous and adds to the bad gases liberated on detonation.

It often happens that when a slow decomposition takes place certain gaseous products are evolved more copiously than others, with the result that the final detonation of the remainder of the explosive adds to, rather than diminishes the noxious vapors given off. Under these circumstances, the number of possible decompositions of any explosive substance are manifold, the reactions depending on the temperature, pressure and the quickness of heating.

Among the numerous modes of decomposition of a given explosive substance, those which develop the greatest heat are those which give the most violent explosive effects, all things else being equal. On the other hand these reactions are not the ones that become manifest when the lowest temperature of decomposition is reached. If, therefore, an explosive body receives in a given time a quantity of heat which is insufficient to carry its temperature up to a degree which corresponds to its most violent reaction, it will undergo a decomposition which will disengage less heat, or even absorb it, and by this decomposition become completely destroyed without developing its most energetic effects. In short, the multiplicity of possible reaction involves a complete series of intermediate phenomena.

According to the mode of heating, it may happen that several methods of decomposition will succeed one another progressively. This succession of decompositions gives rise to even more complicated effects, as instead of causing a complete elimination of the decomposed part, it may result in the division of the primitive substance into two parts; one of which is gaseous, becoming eliminated, and the other solid or liquid, which remains exposed to the consecutive action of the heat. The composition of this residue being different from the original explosive substance, the effects of its consecutive destruction may become completely charged from those of the original explosive. This is shown by the solid residue often left by burned dynamite.

Such are the causes, some mechanical and some chemical, owing to which nitroglycerine or other high explosives give such diverse effects, according to whether they are inflamed, heated or exploded by means of a detonator charged with fulminate of mercury.

In regard to the relative efficiency of explosives when burned and when detonated, Roux and Serran give the following results calling the effects obtained by means of gunpowder unity.

	Detonation.	Inflammation.
Nitroglycerine	10.0	4.8
Compressed Guncotton	6.5	3.0
Picric Acid	5.5	2.0
Potassium Picrate	5.3	1.8

In practice the fact that an explosive has not been properly detonated is made manifest principally by the production of considerable quantities of disagreeable and poisonous fumes, the presence of unexploded powder, the small amount of work done by the powder, and often with high explosives a section of the borehole in which the powder has burned is unaffected. As already mentioned, the bad fumes in incompletely detonated powder are due to the fact that its decomposition was effected at a temperature below that which corresponds to the most violent chemical action. The result is that instead of producing nitrogen and carbon dioxide in the gases from the explosion, both the poisonous nitric oxide and carbon monoxide are formed.

The weaker effect from imperfectly detonated powder is due largely to two causes; the lesser heat of formation of carbon oxide gas and the heat absorbed in the formation of nitric oxide. According to Boyles Law, the pressure of a gas increases proportionately to the temperature. Thus when carbon monoxide and nitric oxide are present in the gases from an explosion, we should have and do get poorer results than when carbon dioxide and nitrogen are liberated.

Further investigation during late years has shown the presence of volatilized nitroglycerine in the fumes from burning or incompletely detonated dynamite. Nitroglycerine is very volatile, and a small quantity may easily be evaporated by the heat from burning powder. This is made manifest by the action of these fumes on human beings. It is a very common fact that men, breathing the fumes from nitroglycerine explosives, in particular when improperly detonated, get violent headaches, similar to those due to slight nitroglycerine poisoning. This great similarity and the fact that the same treatment effects a cure in both cases, is accepted by quite a number of authorities as satisfactory evidence that nitroglycerine vapor is present in the fumes from poorly detonated or burning dynamite.

The causes of incomplete detonation are very numerous.

It may be due to weak detonators, damaged or wet detonators, improperly made primers, spaces between the cartridges in the boreholes, contact between the fuse and the powder, causing the powder to be inflamed from the fuse, a displaced detonator, insensitive powder, frozen powder, etc.

When an explosive is somewhat insensitive the use of a stronger detonator will often overcome this difficulty. Some granular powders, which are made into cartridges, have a tendency to become hard and insensitive. With these a kneading of the cartridges with the fingers will loosen up the powder, whereupon it regains its original sensitiveness. The effect of heat on the sensitiveness of an explosive has already been discussed.

The admission of a small amount of moisture to the charge of any detonator very appreciably affect its strength. Thus it is fairly common in cases where blasting caps and electric fuzes are not stored or transported properly, for the detonators to lose so much of their strength that they are not capable of exerting the amount of energy necessary to develop the most violent explosive reactions in the explosive with which it is used. Therefore the greatest care should always be taken to keep all detonators in a dry place, away from all moisture.

Some explosives appear to get insensitive under the influence of great depths of water. As a matter of fact this is due to the great pressure which lessens the effective shock that the detonator would exert at ordinary atmospheric pressure. Therefore for blasting in great depths of water such as are to be found in some deep drill holes, nothing less than a No. 8 (30.8 grain) detonator should be used.

VELOCITY OF DETONATION.

The velocity of detonation or quickness of an explosive is often as important a point to consider as its strength in the selection of dynamite for any work in particular. The greater the rate at which an explosive is decomposed on detonation, the greater will be the crushing and shattering effects. According to Berthelot, there is a direct relation between the sensitiveness of a high explosive and its quickness or rate of detonation, because with a powder that is easy to detonate, the explosive wave is propagated with much more ease than is the case with one not so sensitive to detonation.

In explosives containing liquid nitroglycerine, the quickness depends on the actual amount of nitroglycerine contained, thus with the straight dynamites the quickness increases directly with the strength.

In the ammonia dynamites the quickness increases in proportion to the actual amount of nitroglycerine contained. The quickness decreases in a very marked manner when the percentage of nitroglycerine is constant and the proportion of ammonium nitrate is increased. Thus the quickness or velocity of detonation of ammonia dynamite does not necessarily increase with their strength, because an increase of ammonium nitrate will increase their strength but at the same time reduce their quickness. As a matter of fact, however, the regular grades of ammonia dynamite on the market are made up so that their quickness is only slightly below that of the corresponding grades of straight dynamite. The principle of the effect of the relative amounts of nitroglycerine and nitrate of ammonia is of great value in the manufacture of special explosives for certain classes of work, sufficiently large to warrant a departure from the regular formulas.

The gelatins from 35 to 80 per cent strength are all very slow in their action, but under the influence of a primer of straight dynamite of 40 or greater percentage strength or of blasting gelatin their action becomes very quick. Blasting gelatin is the quickest as well as the strongest explosive on the market at the present day. In tight blasting good results are often obtained by placing one or two cartridges of a very strong explosive at the bottom of each hole. When this is done care should always be taken to use a dynamite that is as quick or quicker in its action, at the bottom of the hole as the one loaded above it. If a slow explosive is used at the bottom, the quicker one above will open up the rock so that part or all of the effect of the strong slow explosive is lost.

JUDSON POWDER.

Judson Powders are a mixture of a crude black powder, with percentages of nitroglycerine varying from 5 to 20, which forms a coating on the grains. This nitroglycerine not only adds to the strength of the black powder, but it is also a detonating agent. The detonation of the nitroglycerine on the surface transmits vibrations of sufficient magnitude to the interior of the grains of black powder to detonate them perfectly. Thus Judson Powders can be regarded as low grade dynamites, as regards their explosive action.

The principal use of Judson 5 per cent, the brand most commonly sold, is to blast in soft rock, which contains so many seams and cracks that black powder would blow out through these seams, doing little or no work. Judson is also used to considerable extent in some of the Anthracite Coal Mines, but this is of secondary importance.

The powder is granular in form, which, as already described, makes it necessary to use a very strong detonator to produce an explosive wave sufficient in strength to overcome the deadening effect of the interstitial spaces and detonate the entire charge.

It is claimed by some miners in the Hazleton, Pennsylvania Anthracite District, that Judson can be detonated in charges up to 5 pounds by means of a No. 5 detonator. This has never been investigated closely but the results are satisfactory to the miners.

As Judson is often used in blasts containing upwards of 100 pounds to the charge, it would be impracticable to manufacture a cap or electric fuze of sufficient strength to insure the proper detonation of a charge of this size. To accomplish this a primer of straight dynamite is used. Careful experiments have shown that the dynamite used for this purpose should be straight 40 per cent or stronger, the stronger the better. The proportion to use is one pound of dynamite to every 25 pounds of Judson. The best effects are obtained when the cartridges are tied in a compact bundle, with the primer in the centre. When blasting by means of cap and fuse great care should always be taken not to allow the fuse to come in contact with the Judson as all grades of Judson Powder are extremely inflammible.

Judson is also often used in giant blasts that require from one carload of powder up. In these blasts there should be several electrically connected primers, distributed through the charge so as to insure complete detonation throughout the entire mass of powder.

USE OF BLACK POWDER TO DETONATE DYNAMITE.

Berthelot states that black powder will explode nitroglycerine, but will not detonate dynamite. Under ideal conditions dynamite can be detonated by black powder provided the confinement be sufficient. However, this is strictly an explosion caused by heat and a certain amount of the dynamite must necessarily be burned before enough heat is generated to explode the remainder. This is a practice to be avoided at all times.

In the Anthracite District of Pennsylvania the writer has witnessed some shots where black powder and dynamite were used in the same bore hole, and has discussed this practice with practical miners.

According to them, the dynamite is used to cut out the coal at the bottom of the holes in hard spots. There are two methods of placing this dynamite. The one that appears to give the best results is where in making up the black powder cartridge the dynamite, with a blasting cap imbedded in the top, is placed in the bottom and then packed into place with black powder. The other method is to place the dynamite cartridges in the bore hole, with a cap in the top cartridge, and then place the black powder cartridge on top of that. The hole is tamped well and fired by any of the ordinary methods.

The idea of this practice is that practically all of the black powder is burned before the fire reaches the blasting cap and explodes the dynamite. Thus after the black powder has burned and exerted its full explosive force and the main body of coal has perhaps begun to fall, the dynamite explodes and cuts everything out cleanly to the point of the hole. This is particularly efficacious where there is a very heavy burden on the point of a hole. This method of blasting has been in fairly common use for difficult shots in some of the non-gaseous anthracite mines, and in the estimation of quite a large number of practical miners in the Pennsylvania Anthracite District is considered good practice.

DYNAMITE AS A PRIMER FOR BLACK POWDER.

Dynamite is used almost exclusively at the present time for exploding large charges of black powder. The advantages of this practice are first, it is easier to place the ignitor in the centre of a charge and there is less danger of its being displaced when a cartridge of dynamite is used; second, the heat, flame and pressure from the explosion of a cartridge of dynamite causes a much more rapid rate of burning and therefore a quicker and more violent action from the black powder. This practice also assures good results when a line of holes loaded with black powder are fired simultaneously by electricity. In very large charges two or more primers can be electrically connected and used to very good advantage.

ELECTRIC VS. CAP AND FUSE BLASTING.

Blasting by electricity, where it can be used, has many advantages over the other method, as regards saving of time safety and work done. When blasted by electricity all holes are exploded simultaneously, and there is no possibility of a second explosion. Any misfire, due to improper connections will not hang fire and explode unexpectedly as sometimes happens when blasting with caps and fuse. When a round of holes is fired simultaneously by electricity, the execution done is much greater than would be the case if these holes were fired singly. Of course, there is a great deal of blasting, particularly in mines, where electricity cannot be used to such good advantage as the cap and fuse method.

CONCLUSION.

In conclusion it has been shown that the use of strong detonators is of the utmost importance in order to secure good results. This fact is recognized in Europe to be of such importance, that with the exception of their Dynamite No. 1 (75% nitroglycerine, 25% Keiselguhr) the use of any detonators of a strength less than No. 6 is prohibited by law. By doing this the proper detonation of the charge is assured. Also strong detonators overcome many of the possibilities of misfire, burning and improperly detonated powder, due to displaced cap, spaces between cartridges in a bore hole, insensitive powder, etc.

All explosive substances become more sensitive as their temperatures approach that of decomposition. Walke sums this up by saying "All nitroglycerine preparations, when gradually heated up to their exploding points, become extremely sensitive to the least shock or blow."

As a rule explosives that are quickest in their action are the most sensitive. The admixture of foreign matter lowers the sensitiveness of an explosive compound in proportion to the amount of this foreign matter that is used.

Explosives containing liquid nitroglycerine are the most sensitive. This sensitiveness is in direct ratio to the amount of nitroglycerine in the explosive. Gelatins are less sensitive than those containing liquid nitroglycerine and granular powders are the most insensitive of all.

It is possible to manufacture explosives the gases from which are not poisonous but it is impossible to have an explosive whose gases will sustain life. The detonation of almost all explosives on the market today, when complete, produces hardly any injurious vapors but when they burn or are incompletely detonated they produce over 80 per cent of mixed nitric oxide and carbonic oxide, which are poisonous.

In regard to quickness, the sensitiveness of an explosive to detonation has a direct bearing on its velocity of detonation. When a primer of 40 per cent or stronger straight dynamite is used with gelatin, their quickness exceeds the corresponding straight grades by about 10 per cent. This can be used to good advantage in tight blasting in hard rock, the density of the gelatins also being of considerable aid. The gelatins are also best adapted for blasting where the water conditions are unusually severe.

Black powder alone will not detonate dynamite completely but it is often used in connection with dynamite in the bottom of the bore holes with a cap properly placed to insure the complete detonation of the dynamite. Also dynamite can be used to advantage as a primer for large blasts of black powder.

The question of handling explosives can be summed up as follows: Keep powder and detonators apart until they are ready to be used; Keep the powder, fuse and caps dry; always thaw nitroglycerine explosives slowly at moderate temperatures preferably not to exceed 80 degrees Fahrenheit, with the cartridges lying on their sides; in short to be careful and use every-day common sense.

DISCUSSION.

J. H. HEARDING—There is a point in this paper in relation to our work on the Mesaba Range where we are constantly using explosives in extremely cold weather. I made a few experiments myself with a bichromate powder which was a light yellow material and non-freezing. I think I used 500 lbs., or 1,000 lbs., and it was prepared in exactly the same form as dynamite but would not freeze. I understood in talking with Mr. Orr that the explosive was known as "Jovite."

C. S. HURTER—Are you sure it was "Jovite?" Jovite is a picrate powder. The general characteristics of picrate powders are their insensitiveness and bad fumes.

J. H. HEARDING—Yes, I think it was. This material which

I tried, had bad fumes but no smoke. I exposed it in the open air and placed the hole so near the face of the breast that the entire charge would be thrown out into a large open pit as I wanted to see if there was any smoke visible and there was hardly any but the odor was very disagreeable.

C. S. Hurter—I don't think it was Jovite. Jovite has not been on the market, to the best of my knowledge, for three or four years.

J. H. Hearding—Well I was the man that got it. I got 1,000 lbs. of it. The effect was as good as dynamite and when it was fresh there were no gases that would obscure an ordinary underground mine. The fumes were rather disagreeable so I would not recommend it and did not feel that it would be a satisfactory powder to use underground, but using it in large open pits, where the matter of ventilation is immaterial, I found it very useful, providing it would remain constant and not dangerous to handle. I do not know whether any experiments have been going on in regard to a non-freezing powder and I wanted to find out whether there were, because we liked this other powder very much in our work as it saved a lot of trouble and a great deal of danger. As this was an experiment, the powder was furnished at the ordinary price of dynamite. I found that when it was fresh it worked as well as dynamite and was a very effective powder for us in the open pits in the winter time.

C. S. Hurter—Your description covers Jovite fairly well. We are still working on that subject but up to the present time the results have been unsatisfactory as regards economy. So far the low freezing powder is the most satisfactory. The freezing point is variable, but we know that as long as water will not freeze, the powder will not freeze also. However we have had several tests and experiments under observation, with non-freezing powders.

J. H. Hearding—Of course you understand that we are using an enormous amount of dynamite. I presume Mr. West's district is using—well I won't attempt to say what it is—but when a man is using a ton a day, which is not infrequent among these large stripping operations on the Mesaba Range, the expense and the danger of thawing dynamite with the thermometer 30 to 60 degrees below zero becomes rather serious and I wanted to know if they were not experimenting on a non-freezing powder.

C. S. HURTER—Yes, we are working on that all the time. Are there any other questions?

JOHN T. QUINE—There is a matter I would like to bring up for discussion and that is in regard to the packing of the caps in boxes. When the cover is taken off a box of caps, they are entirely exposed to everything, such as candle grease, sparks, etc., which might be the cause of an accident involving the loss of life. I think possibly they could find some means of putting the caps in the boxes, reversing them, or placing them on their sides. I would like to hear from some others on that point. It has been spoken of at different times by the men in charge of mines in Marquette county.

C. S. HURTER—Well the subject of the packing of blasting caps is, of course, something of great concern. In the first place we have to satisfy the Bureau of the Safe Transportation of Explosives in connection with the packing. Now these blasting caps must be packed in the boxes so that they cannot move—they must be packed firmly. Of course outside of the box, there must be a certain amount of saw-dust between the boxes and the cases in which they are packed. Now in Europe today, and formerly in this country, it was the custom when caps were placed in the box, to fill the caps and box with a fine saw-dust. Now in connection with that, we find first that fine saw-dust attracts moisture which would cause a deterioration in the strength of the caps. In the second place we find that there were quite a number of accidents indirectly caused by dampness which would make the saw-dust stick in the cap. Accidents sometimes occurred when a man would take up the cap and try to pick out the sawdust sticking inside with a pin or nail, or try to knock the sawdust out by rapping them violently. We then did away with the sawdust. We now have a piece of paper a good deal like stiff blotting paper, bearing a small depression that fits snugly in the top of each cap, which is placed upon the caps and pressed down. We find that this method holds the cap in place more firmly than any other method that has been tried. When you pack them on the side, you cannot get the piece of blotting paper to hold them absolutely firm, and if we tried any method that would not hold them rigid the Bureau of the Transportation of Explosives would object. Now if we turned them upside down and packed them, the trouble would be that we could not get the caps fixed so firmly by pressing them on the paper as we can by pressing the paper on the caps. Now in regard to the action of hot candle grease and sparks. The capsule proper is made out of a very high-grade copper and is very thin, and is a good conductor of heat. I am positive in my own mind that a drop of hot candle grease falling on the bottom of the cap would explode it just as quickly as if it fell in the open end and the same would be true in the case of sparks falling on the outside of the caps. Then again after the men have taken a few caps out of the box, the others commence to fall on their sides and in that case you have practically no difference in conditions after the first half dozen caps have been removed, but I think a great deal of the danger is that the men in working with the light on their hats pick up the caps and look into them to see if they are clean. Thus it would make no difference how the caps were packed in the box as regards probability of accident. This is a subject we have gone into very thoroughly and it seems to me that there is practically no difference whether the caps are packed upside down or open-end up as regards accidents from anything dropping on them. And then on the other hand if the caps were packed that way the men might be tempted to be a little more careless under conditions where the danger was the same as if they were packed open-end up. Do you think that covers your point?

JOHN TREBILCOCK—I would just like to say a word, and that is on having the caps placed in a safe position so that when the miner takes them out of the box he will not knock them around as you know the jar will sometimes cause the cap to go off. When he takes the cover off the box and after the first row is gone they are scattered all over the box and then they are liable to go off. In that case they are shaken all over and if there was something gotten up so that the miner could take out a few caps and the others would remain in the position they were put in, I think it would guard against accidents.

J. H. HEARDING—How would it be to put them in paraffine wax?

MR. HURTER—The melting point of paraffine or that of any of the ordinary waxes is sufficient to cause explosion of the caps.

J. H. HODGSON—This matter of caps and blasting I have thought over considerably and I think that every man who has charge of mining operations underground gives it a good deal of careful attention. At our mines in Negaunee, when I took charge of them some three years ago and up to about one year ago, we used to have individual thawers to thaw our powder. We were working about 500 men underground, and I got so nervous in going through the places and seeing the men so careless with their thawing operations that I finally decided the best thing to do was to put in a central powder thawer, so we put in an electrical affair. Any excess powder they are instructed to take back to the powder house so that there is no powder left laying around. That has solved our powder question and we have had no trouble since then and that also solves the cap problem as a man now asks for the length of fuse, number of caps and quantity of powder he wants. We also did that at our other mines and I understand that other operators have done the same thing. There is one instance that came to my attention about one month ago which is somewhat unique and is something that I have never seen before and think it might be of interest to mention it here. On the night shift we had some men running a drift with two machines, and with the trammers made six men in the drift. On going off shift they blasted several holes and one hole missed fire. The day shift went down and went to work and in moving the dirt they found a missed hole, but, like other men, were careless and did not blast it. The only safe thing was to blast the hole at once; however they didn't do that and intended to blast it at noon or some other time. They didn't observe any smoke coming from the hole. About 8:30 the shift boss in making his rounds went into this place and in examining the drift he noticed some smoke coming from this hole and he told the men to get out immediately and they just got out when the hole exploded. The hole hung fire for two hours. Of course it was a case of pure carelessness on the part of the men, but it was rather a peculiar thing to see a hole hang fire for two hours.

C. S. HURTER—That was probably caused by a defective fuse. In the body of the fuse, and particularly some of the cheaper grades, there is more or less cotton used, but in higher grades they use material that very rarely, if ever, smoulders. In the higher grades of fuse, no cotton is used except the small thread in the powder train. The countered fuse, that has a cord winding instead of a tape, has proven more satisfactory than the tape on account of its flexibility.

J. H. HEARDING—I would like to ask the captain if the powder man keeps his caps in the same house that he does the powder.

J. H. HODGSON—Yes, sir. In a separate room, but in the same building.

J. H. HEARDING—I should think that it would be a rather dangerous practice.

J. H. HODGSON—If the thing goes up it will kill only one man and destroy the building anyway. I think however, that our plan is a very good one.

C. S. HURTER—I have been in that powder house myself during the past week and there is a pretty substantial wall between the rooms and the powder is not placed up against the wall separating them.

J. H. HEARDING—Our practice is to have no caps within 200 feet of the powder.

C. S. HURTER—In regard to the question raised by Mr. Quine regarding candle grease dropping on the outside of the cap. When an explosive is hot it is more sensitive to shock than when it is cool. When candle grease drops on a cap the result is that the shock and the heat strike simultaneously and that would probably cause an explosion under those conditions.

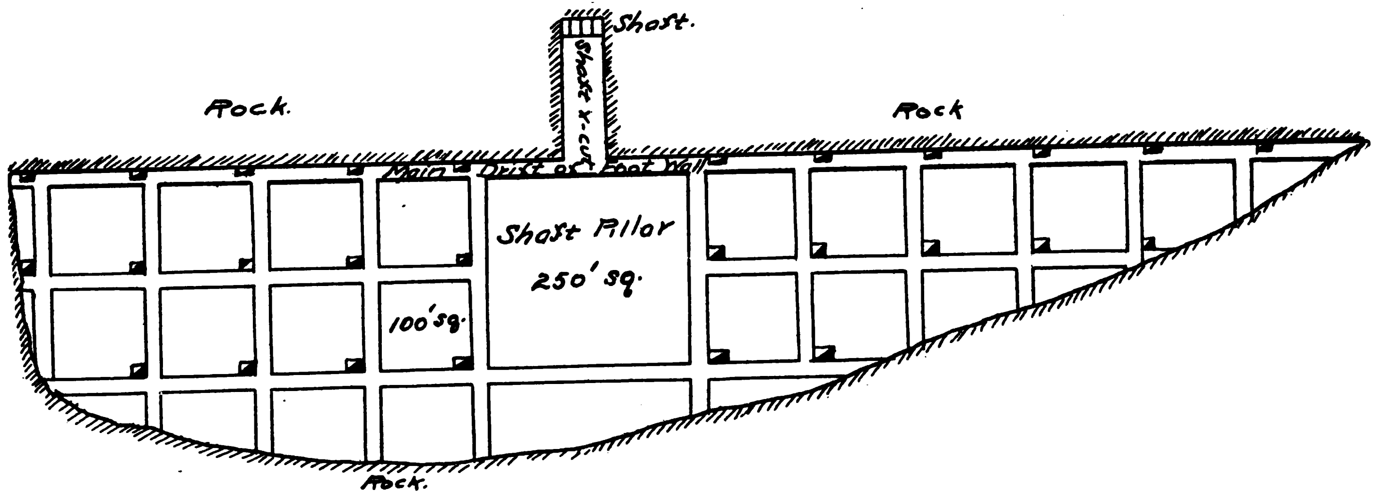
UNDERGROUND METHODS OF MINING USED ON THE GOGEBIC RANGE.

BY PERCIVAL S. WILLIAMS, RAMSAY, MICH.

The system of mining generally used on the Gogebic Range is known as the top slicing system. It differs, however, from the top slicing system used in the underground mines on the Mesaba Range in that a pillar of ore about eight feet in thickness is left over the back lagging on the sub-levels during the development stage and during the driving and timbering of the slices in the sub-level pillars themselves, whereas, on the Mesaba range, the new slices are timbered up to the floor boards of the sub-level above, leaving no ore to pull back in retreating except what they are able to mine out on the sides of their slice, sometimes a slice on each side of the opening slice and again a slice on one side only.

Before going further into this system of mining it would be well to give you a general idea of how the levels and sub-levels are opened up or developed before this actual mining takes place. In finding a new ore body its limits are first established, drifts and crosscuts being driven to determine the length and width of the ore body and 4x7 raises put up from the drifts at 25, 50 or 100-foot intervals to prove its height. (See sketch No. 1).

As the raises are advanced they are cribbed up with about six-inch round timber, opening sets being put in them at the proper intervals for the sub-level openings so that the work on these sub-levels can be started at any time without delay. Poles are laid on top of these opening sets to support the cribbing put in the raise as it is continued above the sub-level. These opening sets consist of two 7-foot posts and a cap on each end


Shaft.
Shaft x-cut
Rock.
Rock
Main Drift on Foot Wall
Shaft Pillar
250' sq.
100' sq.
Rock.

Sketch No. 1.

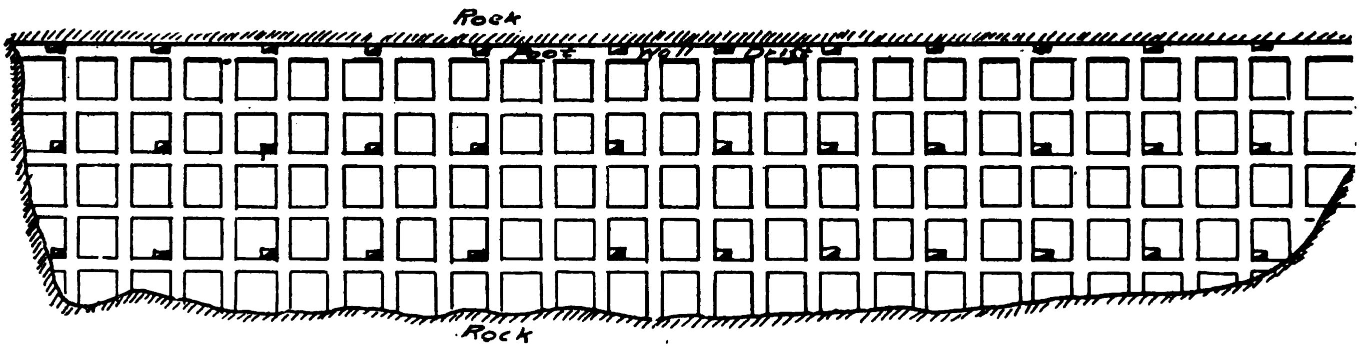
of the raise, and are put in the raise sixteen to eighteen feet apart from floor to floor. This allows for a pillar of ore 7½ to 9½ feet thick from the back of a sub-level to the floor of the next sub-level above. Whether these sub-levels are developed as soon as reached with the raises or not, depends on the condition of the ore reserves in the mine to a large extent. If the ore is needed to keep the product of the mine up to the required point they are developed at once, but if the management does not need ore from the section of the mine in which this development work is being done the sub-levels would not be developed until a short time before the ore was to be mined. This latter method of simply putting up the raises and placing opening sets at the sub-levels until the limit to which the ore body goes up is reached, is by far the most satisfactory, as it permits reaching the top of the ore sooner and makes unnecessary the extensive repair work on the sets of timber that would have been put up in the sub-levels if the development work had been done very long before slicing on the sub-level began. This last feature of additional cost is particularly serious in case the mine might have to be closed down for a period of time for some unforeseen reason. Frequently, however, ore reserve conditions are such that it is advisable to develop the sub-levels as rapidly as possible, thereby placing more men at work and increasing the hoist materially. This is a problem for each mine to work out for itself, but it is generally conceded that development work on the lower sub-levels should be done only in sufficient time to mine them out to best advantage.

It is probably apparent to all that the top of the ore body has to be reached and a sub-level developed as near the top as possible before the actual slicing can begin. The sub-levels are developed in much the same manner as the main levels, except that the ore is generally blocked out in 50-foot pillars instead of 100-foot pillars as some of the main levels are developed. In one of the mines on the range the main levels are developed with parallel drifts spaced so as to leave 35-

foot pillars between them and only occasional crosscuts are put in. Electric haulage is used on such levels. Raises are put up 25 feet apart. Where the main levels are blocked out in this manner the sub-level pillars are only 25x35 feet. The advantage gained by blocking out the ore in this way is in having the raises at more frequent intervals on the sub-levels and in producing less curves and crossings on the main level tracks. The crosscuts on the sub-levels run directly over those on the level so as to connect with the raises put up in the ore body from the main level crosscuts. The sub-level drifts are also driven so as to connect with the raises put up from the main level drifts or cross-cuts, and when fully developed the plan of this sub-level would show the ore body cut into blocks about forty feet square with raises at the corners through which to dump the ore to the main level. (See sketch No. 2).

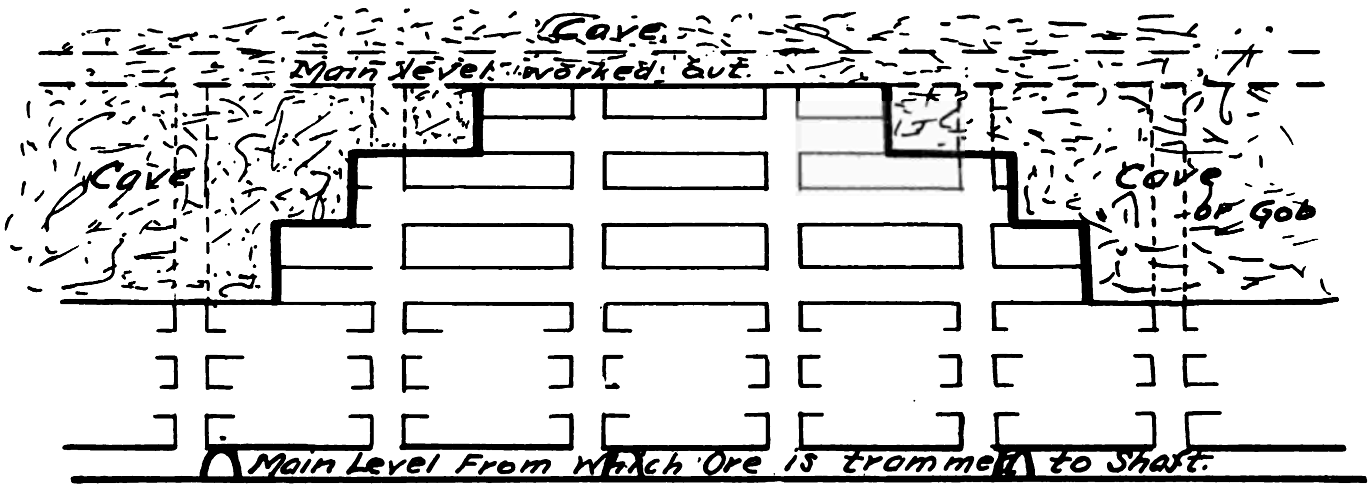
The sub-level will have a more or less irregular outline on the hanging side depending upon the manner in which the hanging rock or capping occurs. Small cars or buggies with about one-ton capacity are taken up to the sub-levels on which they are to be used. Timber and lagging are usually lowered from a timber raise in the shaft pillar to the sub-levels in the same manner. It is sometimes necessary to hoist the timber and supplies from the main level below, however, in which case small puffers run by air are made use of. Eight pound or sixteen-pound rail is laid in the drifts and crosscuts on the sub-level floors on which to run the buggies, and in some cases only crosscuts have rail in them, turn sheets being placed at the intersections between the drifts and crosscuts, and 2"x4" hardwood is used for rails in slicing out the ore.

We will now assume that the top sub-level is fully developed and the next sub-level below developed to such an extent that when the slicing is well under way on the top sub-level it may be commenced on the next sub-level below. The ore is sliced out in nearly the same manner at all of the mines, slicing starting at the contact between the ore and the rock on the hanging side and ends, and progressing back toward the



Sketch No. 2

foot-wall or shaft pillar, which ore is usually mined out last. Two gangs of miners usually work on each pillar, starting on opposite sides and running drifts or crosscuts parallel and next to their previous openings, toward each other until they meet. The openings made by them are timbered up with 7-foot timber and the back and side against the ore lagged up. After meeting, the gangs start to retreat in the openings made by them, breaking down the ore over the caps to the floor of the sub-levels where either the miners or laborers furnished them, shovel it up into the buggies and tram it usually to the nearest raise, rarely over 50 to 75 feet away. After reaching the original drift or crosscut from which they started and having previously covered the floor of the mined out portion of the sub-level with boards or lagging to enable cleaner extraction of the ore under them, they start another slice as before, either leaving about six feet of ore between them and the mined out portion, to be mined out when they start to retreat again and take the ore over them, or their slice is driven along side of their previous slice. Where the latter method is used, however, the ore over the top of the caps used in the first slice is usually left to support the cave until the second slice is driven, after which the ore over the first slice is removed. The ore over the second slice would be taken out after the third slice had been driven. When mined out in this way the timber and side lagging put in place with the previous slice is depended upon to hold the cave back long enough to remove the ore over the slice against the side of which the cave is pressing. In this manner the pillars are gradually pulled back to the safe points of final retreat from the sub-level until the entire sub-level is mined out. In the meantime, however, mining operations are well under way on the lower sub-levels, it being our object to mine back the sub-levels at the same rate of speed, always having the miners, that are working on the next sub-level below, working under the cave produced by the men working above them. In this way either a longitudinal projection or a cross-section would show the ore in place at

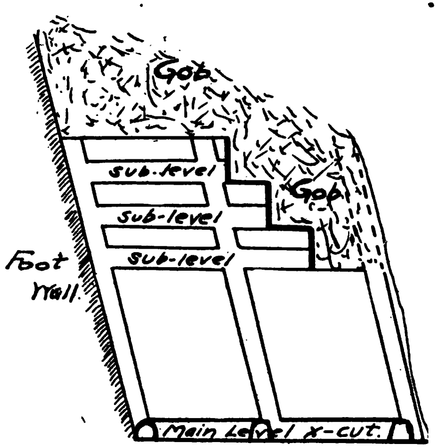


Cave
Main level worked out.
Cave
Cave or Gob
Main Level From Which Ore is trammed to Shaft.

Sketch No. 3.

any time, forming a succession of steps covered over with gob or waste material. See sketches No. 3 and No. 4).

Any rock encountered in mining out the slices is thrown back into the mined-out portion. The timber is usually broken with the blasts and also left behind. In this way a gob accumulates, which in the course of time aids materially in holding up the cave while the ore over the slices on the lower sub-level is being mined out. It is advantageous to have the rock capping break down of its own weight on the cave soon after the immediate ore underneath it is removed, but at times this capping hangs up for a long period, and we have to depend



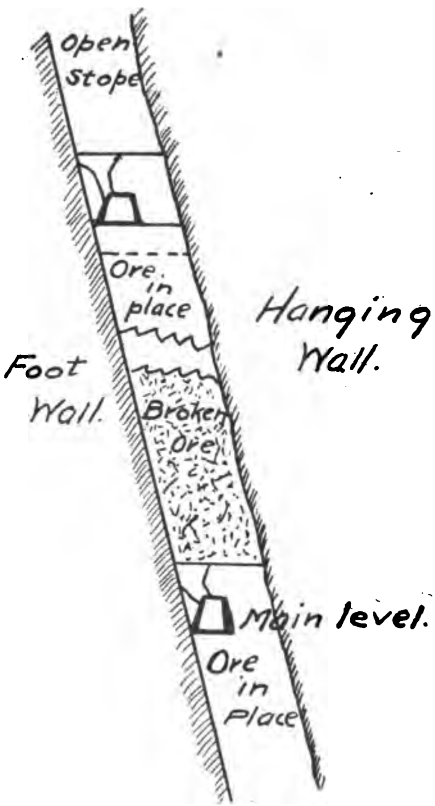
Sketch No. 4.

upon the cushioning effect of the accumulation of rock and timber, left in the opening during mining operations, to prevent a heavy fall of hanging or capping rock from crushing the pillar and timber used to protect the miners. Some of our ore deposits have extended close enough to surface to make the surface follow down with the cave, but frequently with smaller ore bodies the surface does not follow readily. This system never exposes a miner to an open stope where there is danger of his falling into the stope or being injured by a fall of rock from overhead. Raises occur at frequent intervals into which men might fall from the sub-levels. The ore compartment of these raises, however, has pieces of steel rail placed across it spaced about ten inches apart, and the ladder road has a trap door at each sub-level, which makes it unusual for a man to be injured in this manner. Accidents will happen, however, as long as there are mines, and the best we can do is to be on the alert to see that all the precautions we can take are properly executed.

Before closing my description of this system of mining I might state that there is a growing tendency among operators to reduce the distance between raises, thereby causing as little shoveling of ore into cars on the sub-levels as possible. Also covering the sub-level floors with lumber, to help support the cave when mining the sub-level underneath, seems to be growing in favor, even where the gob above is compact enough to enable a good extraction of ore without the use of boards. One thing is certain, and that is that the exposing of floor boards by miners on the sub-level below lets them know definitely when to stop work towards the cave above them and helps the bosses to keep the grade of ore from being lowered by the miners running waste material into it.

While probably 95% of Gogebic Range ore is extracted by means of the top slicing system, certain conditions are met with in places which make other methods more feasible, and I will enter into a short description of them.

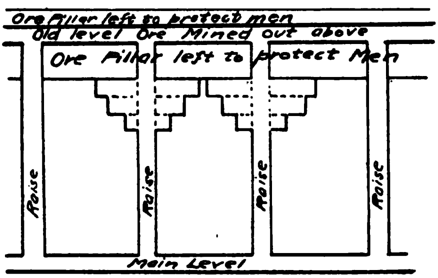
Where the ore deposit is narrow, say from six to twenty feet wide, it is frequently quite hard, and developing the ore with sub-levels would prove too expensive. Where it is not necessary to make more than one grade out of such ore deposits it has worked out very nicely by the use of the back stoping method, the underhand stoping method, or a combination of the two. No timber is used in any of these methods. The main level is first drifted on and raises put up about 15 feet apart to the first sub-level which is driven so as to leave about ten feet of ore between the back of the main level and the floor of the sub-level. The raises are widened out at the floor of the first sub-level to enable them to accept ore from more territory. Up to this point all three methods are alike. In back stoping the ore is broken by blasting in the back and drawing only enough broken ore from the chutes to let the miners have room to work. Care must be exercised to prevent so much ore being drawn out as to make it difficult to reach the ore in place from the loose pile under foot. The stope is carried up in this manner within about six feet of the



Sketch No. 5.

level, where, if there is waste material resting on the floor of the upper level, the ore is all drawn out before proceeding farther. In case no waste material is resting on this upper level, miners then go to the upper level and take the ten-foot pillar above the level and at the same time break the six-foot pillar under them a little at a time, starting at the point farthest from their means of escape, and retreating toward the shaft or limit of the stope. In case waste is being held up by the floor pillar the waste should have been supported by stulls. Otherwise when the pillar finally falls to the chutes below it will be mixed with waste and some ore lost in consequence. (See sketch No. 5).

In the underhand stoping method raises are continued through to the level above, usually 100 feet. Miners then start to drift on each side of the raise, leaving about six feet of ore between them and the level above. As soon as they are ten or fifteen feet away from the raise other miners start to break the ore that formed the floor for the first gang of miners. These miners are in turn followed by others a step lower down,

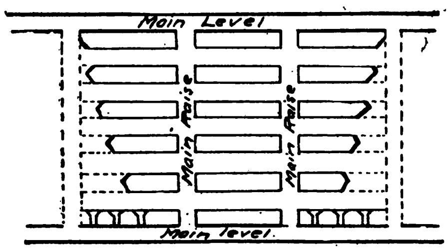


Sketch No. 6.

and the stope is gradually worked out in this manner, the broken ore running into the funnel shaped raise without much shoveling in the stope. The hanging wall must be very strong and absolutely self-supporting in order to make this a safe system of mining without the use of timber for stulls. This method is more susceptible to successful grading than the back stoping method, but both are much inferior to the top-slicing method in this respect. The pillar left under the floor of the upper level is blasted down into the stope from the upper level after the stope is mined out, and serves merely as a protection to the men while working in the stope from anything that might fall from above it. (See sketch No. 6).

The combination of both of these methods has been used after the narrow pillar between main levels had been developed or cut up with sub-levels not knowing but that the ore might widen out and become softer in height, necessitating the use of the top slicing system. The ore was hard enough not to require timber in the sub-levels and after its limits had been established the miners on each sub-level started at the end farthest from their safe means of retreat and drilled holes which would break half of the pillar above the sub-level and half of the pillar below the sub-level on which they worked, the gang above taking the balance of the pillar above them and the gang below taking the balance of the pillar under them. The lower sub-levels were carried back a little ahead of those above them in order that the broken ore might have a direct drop to the first sub-level to be trammed out through the chutes. (See sketch No. 7).

In closing this description of the methods used on the Go-



Sketch No. 7.

gebic Range, I might say that the ore is generally quite soft in its structure, making it unnecessary to use drilling machines in the ore except occasionally. Holes are bored into the ore with hand augers to a depth of about five feet, and 27% dynamite is generally used to break it. The foot wall on which the ore lies pitches to the north at a 60 to 65-degree pitch and the hanging rock usually lies in a plane parallel to the foot wall. The general trend or strike of the formation is Northeast and Southwest.

I wish to acknowledge the kind assistance rendered me in my work in connection with this paper by the different mine managers on the range who gave me free access to the mines and their maps.

DISCUSSION.

J. H. HEARDING—I would like to make the inquiry if by driving the sub-level below and paralleling the drifts immediately below your second sub to those on the first sub, whether you find any difficulty in the ground on the second sub breaking?

P. S. WILLIAMS—No, I don't believe we do. My experience has shown that we have not.

J. H. HEARDING—I have found considerable difficulty in that respect myself.

P. S. WILLIAMS—Where such a difficulty was experienced, it would be a simple matter to split up the pillars underneath; i. e., in developing a sub-level, one could put the cross-cuts in the pillars between the cross-cuts on the sub-level immediately above. The footwall slopes at about a 60 degree pitch, which tends to prevent the weight on a sub-level drift from exerting all of its force on the drift on the next sub-level below, part of the thrust being on the footwall itself.

WILLIAM KELLY—I would like to inquire whether in this system there is any difficulty in getting all of the ore, and whether any precautions are necessary to secure it.

P. S. WILLIAMS—I should say that the sub-level system is as satisfactory as any that has ever been tried on the Range; it is the general practice now, simply for the reason that we get a better and safer extraction with that system than with any former one. There are times when we lose a little ore due to extreme pressure of the cave and the pillar crushing, but in case that happens, we usually come back to the pillar and drift around behind and get the ore that we lost in the original opening; in this way the ore is extracted quite well. We have lost some ore—there is no question about that, and all of our caves have some ore in them but not a great deal, and I think that the use of boards is reducing the loss considerably. Where we gain considerable depth in a cave, we also have the advantage of the self-sustaining power of the cave itself. The waste material in our caves, when much has accumulated, does not follow extraction of the ore nearly as rapidly as Mesaba Range caves. Sometimes they hold up a week or more, but of course, it varies in different mines and depends upon the conditions.

W. A. SIEBENTHAL—In the second method I believe I understood you to say you did not use any timber, but if not, how are the drifts held up? Are they timbered or walled?

P. S. WILLIAMS—The second method, is the "back-stoping" method. The original drifts are timbered. I did not mean to say that the original openings were not timbered—they usually are, but after the actual mining starts in the stope, there is no timber used. Sometimes the drift itself would not be timbered, depending on the strength of the ore that is being driven through. Of course, where raises are put up, we usually have to put up sets on which we spike the planks to support the chutes.

F. W. SPERR—I am inclined to offer a suggestion in reference to the use of the term "Top-slicing" as applied by Mr. Williams. I think it would be better to confine the application of this expression to the method of mining with which I believe it originated. I think the term "Sub-slicing" would be more appropriate and expressive than the other term, for the method which Mr. Williams describes. Perhaps we might go a little further in this matter and agree upon certain terms to represent certain methods of mining in the Lake Superior region, in order that we may use the same language when we meet to discuss methods from different districts. As a beginning in this direction I would suggest the following:

Top-slicing is the method by which the ore is mined off at the top in slices 7 ft. or 8 ft. thick, and directly under the gob or over-burden.

Sub-slicing is the method by which the ore is mined off in slices 7 ft. or 8 ft. thick, leaving a slice of greater or less thickness below the gob or over-burden, and allowing it to cave into the excavation.

Side-slicing and *End-slicing* are modifications of Sub-slicing.

Sub-stoping is the method by which the ore is mined from small drifts made between the main or haulage drifts at vertical intervals of 25 ft. to 35 ft.

Underhand-stoping is the method by which the ore is mined by "down-holes" after a cut has been made over the top of the stope of sufficient size to permit the setting up of the drill for the down-holes.

Back-stoping is the method by which in a general way the ore is broken down into a cut underneath prepared for the purpose. There are many modifications of this method.

Open-pit is the method of mining with all the work open to daylight.

Milling is the method by which the ore is broken into chutes opening into an underground haulage way. The chutes may rise to the surface, making a modification of open-pit mining, or they may end below surface, making a modification of underhand-stoping.

The *Caving system* comprises all methods of mining by which the over-burden, the hanging wall, or any part of the ore, or any combination of these, is allowed to break down or cave under the control of the different methods.

The caving system of mining has been executed by each one of the above defined methods, except the underhand-stoping and the milling; and it is not impossible that even these two methods may be involved in a method of caving.

Block-caving is the method by which a movement and auto-crushing of a large block of ore is effected by means of cutting off the bottom, and cutting off or weakening the ends and sides.

WILLIAM KELLY—I would like to add that this paper is a very useful one. We all know the methods we use in our own mines, but we do not go around enough and see the methods in use in our neighbors' mines. The literature of mining is deficient in descriptions that are up to date on the various methods of mining in different localities, and I want, personally, to thank the author for his paper.

W. A. SIEBENTHAL—I voice Mr. Kelly's sentiments as expressed of the value of this paper. Next year the Institute meets on the Menominee Range, and I believe it would be wise for a committee to be appointed to see that papers are prepared; we ought to ask some engineer of the Menominee Range to prepare papers for presentation next year, showing the different methods used in that district. If this is given to a committee of the Menominee Range, I believe we would have some good papers showing the methods used on that Range and if that plan is followed out as the Institute meets on the different Ranges, in five years time we will have a very good collection of literature showing the mining methods used in the Lake Superior District.

CHAIRMAN—I think that would be a very good idea.

W. A. SIEBENTHAL—I make a motion that a committee be appointed from the Menominee Range members to solicit contributions along this line for the next meeting. (Motion supported and carried.)

F. W. SPERR—I would suggest that one member of the committee be from the Iron River District, one from the Crystal Falls District and one from the Iron Mountain District, these three Districts comprising the Menominee Range.

THE COMPANY SURGEON.

BY E. M. LIBBY, M. D.

(Surgeon Mercy Hospital, Iron River, Michigan.)

In an occupation possessing as great a hazard of personal injury as that peculiar to the mining of iron ore, it is both necessary and humane to provide the employe with immediate surgical attention in case of accidental injury received while in the performance of his work. To provide him with whatever chance attendance that might be available at the time of injury is both impracticable and uncertain. In anticipation of his injury, therefore, a competent surgeon of definitely established ability should be provided and a suitable place for his subsequent care and treatment maintained.

The work of the Company Surgeon includes the care of the employe and members of his family in illness as well as in case of accident. This, then, has made the work of the mine doctor a broad one and has kept him in complete touch with the entire field of general practice as well as with all the details of his more specific work in emergency surgery. It has made the office also, one of greater responsibility. In his development, as a consequence, the Surgeon has gradually become an important factor in every mining community until, at the present time, he must be a most thoroughly competent servant. It is necessary that he be a master in his peculiar specialty, traumatic surgery, a capable general and regional surgeon, thoroughly skilled in the practice of obstetrics, possessing a working familiarity with the methods of the laboratory, and scientific in the diagnosis and treatment of diseases of the adult as well as in the care and feeding of children. Moreover, he must be a man of tact and resource, guarding and anticipating the interests of his patients and those of the employing company. In no other situation in the profession, perhaps, are such demands made as are upon that group which includes the Company Surgeons of the mining ranges. He is the first requisite for aid in any practical scheme for comprehensive attendance to the employes of an organization.

The second requisite is of course, the hospital. Structures carefully designed and erected for this purpose are most essential for the performance of the best work, though a good building does not necessarily, nor by any means, constitute a good hospital. Much of the work that is being done in the homes today, particularly in cases of severe illness, could be much better done in the hospital and some of the work being attempted in the home should never be done outside the hospital. The structure should be adequate to meet all the demands that might be made upon it and its equipment should be complete in all the essential details. The requirements of the family will demand fully as much consideration in the planning of the building as will the needs of the injured worker. Provision for the requirements of the family is essential to its security and well being.

In connection with the hospital, the question of care and attendance presents itself as a matter of course. Here the service of the well trained nurse is to be commended. She is a valuable necessity and, if the truth be stated, much, and often more, depends upon her ministrations than upon any aid that can be offered by the Surgeon.

Another and almost invaluable feature that should be embraced in any scheme of attendance is the visiting nurse. Of the same training as her colleague in the institution, her office is to provide, to some extent, the necessities of attendance received in the hospital. As a help during convalescence after leaving the care of the Surgeon, to insure proper attention to the mother and the new born in the home and in the care of patients outside the hospital, she is indispensible. In the reduction of infant mortality alone, in the congested and sometimes unsanitary locations, her work will more than warrant the cost of her maintenance.

A minor feature, but no less essential in the general scheme, is the ambulance service and prompt response to calls in case of severe injuries so frequently sustained. The ambulance should be thoroughly comfortable and suitable for all classes of this service.

We have, in some measure, outlined the essentials of a practical scheme of aid to the employe and the members of his family in the misfortunes of accident and illness with which he is frequently afflicted. Let us now, in like measure, consider the manner in which this aid has been and is often provided. The exceptions, in which all that has been outlined above are supplied and in which the interest of the employing company has extended to various other and equally worthy directions for the benefit of the employe, were covered very completely in a paper written by Mr. W. H. Moulton, of the Cleveland-Cliffs Iron Co., for the meeting of 1909. Much that is here said is, in many instances, applicable only in part.

In most cases, the service of the Company Surgeon is paid for by an assessment of one dollar made against each name on the monthly pay roll. The total is handed to the Surgeon, in an occasional instance (let us whisper it), in a spirit which would indicate that it was considered a gratuity of the Company rather than pay for adequate service rendered. Except in attending to the collection of this stipend, many of the Companies have given but little systematic attention to the character of the service purchased. From the amount received the Surgeon is now expected to defray all the expense that may be entailed in rendering, with the exception of the visiting nurse, service that will embrace some approach to the complete one outlined above.

Responsible for his own work and often called strictly to account, frequently without justice by the employe, and occasionally with or without justice by the employer, the Company Surgeon must stand responsible also for the acts of his assistants. Standards of medical education and practice have risen greatly within the last few years. The man just entering the profession, from which class the assistant is usually recruited, has spent more years in preparation and more time in college and hospital than most of the older men. He is better prepared to enter practice. Naturally, he demands more for his services.

Hospital facilities are, in only a few instances, supplied by the employing company. The Company Surgeon must supply his own quarters and an institution of any ordinary pretentions cannot be provided and equipped without considerable expenditure. Trained nursing help is also expensive and really essential if the surgeon cares at all for results. In addition, the ordinary running expenses of any of these institutions, coal, light, gauze, cotton, livery, drugs and provisions, not to mention cook, maid, furnace help and laundry, total a comparatively large sum at the close of each month.

Regardless of the number of men employed, more is often expected, by employe and Company alike, than is within the financial power of the surgeon to supply. In other instances, where large numbers are employed and the collection is adequate, the amount returned in service falls far short of anything that should be permitted. While regarded, occasionally, as a part of the Company organization, more often the surgeon is considered an outsider, to be tolerated because he is a necessity. Directly responsible to no one for his work, yet responsible always, for all of it, the Company Surgeon is often between two millstones.

Despite these drawbacks, however, and greatly to their credit, if it may pardonably be stated, the Company Surgeons of the Iron and Copper ranges of Northern Michigan and Minnesota, stand, taken as a whole, superior to any other similar group. The service rendered has been, in general, very satisfactory. The results obtained will average highly in any comparisons to which they may be subjected. In point of service rendered, the hospitals have been well managed, and many of them have and deserve great credit for the good reputations established. A most creditable showing under a system that might encourage the least possible expenditure for service by the surgeon in order to secure the greatest possible personal gain.

It must not be overlooked, however, that there is much room for improvement and that, in some instances, the need is acute. That, from a business standpoint, the service is probably of as great value to the employer as it is to the employed. That which is attempted at all should be done completely and in the very best manner consistent with the attending circumstances. The provision for medical and surgical attention and for hospital accommodation will probably be considered, in time, more of an obligation upon the employing organization, presumably a highly intelligent agent, than it is a burden upon the toiler himself, in most instances foreign born, ignorant of the means and wanting in discrimination.

The Mine Surgeon should be a part of the operating organization. His department should be as distinct as that of "Accounts" or "Engineers." His work should be extended to cover at least in an advisory capacity the housing and sanitation for employes. His assistants should be of his own selection, chosen for their excellence and subject to the approval of the Company. His remuneration should be fixed and adequate. That the best of the men entering the practice of medicine should seek the work, promotion to vacancies and advancement from Assistant to Mine Surgeon should be made subject to merit and term of service. No man should be admitted to the service to which it was not certain he would be a credit. Once admitted he should always be provided for. Modern hospitals should be established and proper nursing attendance organized. The work in the larger companies might, with advantage, be under the supervision of able chief surgeons who would have general supervision over all the work wherever situated. The Visiting Nurse should not be forgotten. What the monthly assessment fails to provide for might in course of time be considered the pleasure of the Mining Company to supply.

Systematized and developed then, there is no question but what, if the same interest was manifested in the organization of this work as is in the development of any other department of the company, it would be but a short time before better attention could not be secured nor a higher grade of medical and surgical service found than would exist within the hospitals and be included in the surgical staffs of the various companies. It might cost a little more, but who would say that it would not yield a rich return? Perhaps, from a plain business standpoint, it might be found to yield a profit in dollars and cents.

The matter is worthy of serious consideration and will demand it within a reasonable time. If this paper has served to bring it to your attention, it will have answered the purpose for which it was written.

THE INDIANA STEEL CO., GARY, INDIANA.

On Friday morning, August 26th, the members made a trip through the new plant of the Indiana Steel Co. which proved an event of great interest. Through the courtesy of E. J. Buffington, president of the company; George G. Thorpe, vice president, and E. T. Bently, traffic manager, a special train was placed at the disposal of the party and the great area covered by the plant was visited, first inspecting the new by-product coke-oven plant now under construction. A stop was made at the ore dock and an opportunity given the visitors to see the ore-unloading machines in operation taking the cargo from one of the company's large ore steamers, and delivering it to the stock pile back of the blast furnaces. The rail mill was then visited where the operation of rolling rails was witnessed. A view was next given of the blast furnaces. A visit was also paid to the two immense powerhouses in which the blower and electric generators are driven by large Westinghouse and Allis-Chalmers gas engines, operated by waste gas from the blast furnaces. Although the Gary plant is still far from finished, its size, arrangement and engineering features made a deep impression on all. The labor-saving devices for the rapid and economical handling of ore and other materials, the provisions for the granulation of blast furnace slag for cement manufacture and the utilization of blast furnace gases for power generation, the great gas and power plant, were all of especial interest, illustrating, as they do, the extent to which economical methods and practices are carried on at this most up-to-date steel works.

The following is a reprint from the booklets furnished by the company and gives further information regarding the work of locating and building the great Steel Works, and also of the City of Gary. It can be seen that the future needs were carefully considered in the laying out of this plant.

The plant of the Indiana Steel Company, known as "Gary Works," is located at Gary, Indiana, on the south shore of Lake Michigan, about twenty-five miles southeast of Chicago. In the spring of 1906 the Indiana Steel Company, a subsidiary of the United States Steel Corporation, commenced

Lake Superior Mining Institute, August 25th, 1910. At Plant of Ryerson & Son, Chicago.

building a steel plant, consisting of eight blast furnaces, fifty-six open hearth furnaces, rail mill, billet mill, plate mills, merchant bar steel mills and a car axle plant, together with auxiliary shops, including machine shop, roll shop, electric repair shop, boiler shop, blacksmith shop, etc.

For the purpose of receiving iron ore, to be smelted in the blast furnaces, a harbor slip has been constructed two hundred and fifty feet in width and five thousand feet long, having a depth of twenty-two feet, affording draft and anchorage for the largest lake steamers afloat. Vessels laden with twelve thousand tons of ore enter this slip and are unloaded by electrically operated ore-handling machinery at the rate of twelve hundred and fifty tons per hour. Running parallel to the vessel slip and in line with the eight blast furnaces located near by is a storage yard into which the ore is placed, the aggregate capacity being approximately four million tons. From this storage yard the ore is conveyed by means of movable bridges and hoists to bins, from which, by gravity, the ore is delivered into an elevator and then automatically delivered into the top of the blast furnaces. The coke and limestone required in operating the blast furnaces are automatically delivered from bins into the top of the furnaces in the same way.

Coke required by the eight blast furnaces will be produced by five hundred and sixty by-product coke ovens, which are now being erected immediately east of Gary Works. As by-products the coke plant will produce gas, tar and ammonia sulphate, the latter being sold as a fertilizer. This plant will produce daily thirty million cubic feet of gas suitable for heating and lighting. The estimated annual production of Gary Works is as follows:

	Tons.
Pig Iron	1,200,000
Open Hearth Ingots	2,700,000
Standard Steel Rails	1,200,000
Blooms and Billets	1,200,000

Merchant Steel Bars	600,000
Plates	240,000
Car Axles	100,000
Coke	1,650,000

The plant site contains approximately nine hundred acres of land bordering on the shores of the lake. To the east of this plant site the Gary Land Company, another subsidiary of the Steel Corporation, owns sufficient land for duplicating the present plant under construction, and the several mills now completed or under construction have been arranged with reference to the future enlargement of the plant.

The blast furnaces are operated by sixteen 2,000 horse-power gas engines, supplemented by four 3,000 horse-power steam engines for emergency. The power required for operating the open hearth plant and steel mills is supplied by seventeen 3,000 horse-power gas engines, which drive an equal number of electric generators. The gas for these engines and for the blowing engines is supplied from the blast furnaces. In this way the power required for the entire plant is supplied from blast furnace by-product gas. Part of the excess electric power developed at Gary Works is transmitted by wires a distance of five miles to the Universal Portland Cement Company's plant and there utilized as power for the manufacture of twelve thousand barrels of Portland cement daily.

The largest individual electric motors in the world are installed in these mills. The rail mill has three 6,000 horse-power electric motors for driving the rolls.

It is estimated that the Gary Works will give employment to between 12,000 and 15,000 men.

In addition to the plant of the Indiana Steel Company, above described, there have been reserved plant sites for other subsidiary companies of the United States Steel Corporation, to provide for their future plant extensions, as follows: American Sheet & Tin Plate Company, American Bridge Company and the National Tube Company.

The American Car & Foundry Company has purchased a plant site comprising approximately two hundred acres of land near the First Subdivision of Gary, and expects at an early date to begin the erection of a car building plant, with a capacity of one hundred and twenty-five cars daily, which will give employment to three thousand men.

The American Locomotive Company has purchased a plant site comprising approximately one hundred and fifty acres of land, for the purpose of erecting a plant to be devoted to the building of locomotives, with a capacity of fifty finished locomotives per month. It is estimated that this plant will give employment to forty-five hundred men.

CITY OF GARY.

The Gary Land Company has acquired ownership of approximately nine thousand acres of land, in one continuous body, and in the spring of 1906 began the building of the City of Gary, primarily for the purpose of providing suitable homes for the employes of the Indiana Steel Company. The City of Gary was incorporated, comprising approximately twenty-seven square miles of territory and including practically all of the land owned by the Gary Land Company. Immediately south of the Gary Works plant site and separated from it by the Calumet River, the First Subdivision of Gary was laid out, comprising approximately eight hundred acres of land. Streets sixty feet in width were laid out in rectangular fashion, with alleys twenty feet in width intervening. Under the supervision of competent sanitary engineers a sewer system was planned and installed throughout the entire First Subdivision. Sewers, gas and water pipes are located in the alleyways, thereby avoiding the necessity for disturbing street paving in the future for repair of service pipes. Each building lot within the First Subdivision has connection with all these utilities.

The principal street running north and south, designated Broadway, is one hundred feet in width, and has been paved with granitoid or concrete blocks. The principal street running east and west, designated Fifth Avenue, is eighty feet in width and has been similarly paved. The remainder of the streets are being paved with macadam.

The First Subdivision will contain twenty-seven miles of paved streets and more than twenty miles each of sewer, gas and water pipe have been constructed.

The supply of water is obtained from Lake Michigan, through a tunnel fifteen thousand feet in length and seventy-two inches in diameter, extending under the bed of the lake to a sufficient distance from the present shore line to insure a supply of water free from pollution. The pumping station is located in the center of the distributing system of the town, and is of sufficient dimensions to install a pumping capacity to supply a population of one hundred thousand.

Gas for domestic purposes is supplied from an artificial gas plant, having a present capacity of two hundred and fifty thousand cubic feet daily.

The electric current for lighting and power requirements in Gary is supplied by generators, operated by the Gary Works.

These three public utilities (water, gas and electric light) are under the control of the Gary Heat, Light & Water Company, a subsidiary of the United States Steel Corporation; franchises having been duly granted by the authorities of the City of Gary.

The Gary Land Company has built five hundred dwelling houses, varying in cost from twenty-five thousand dollars to fifteen hundred dollars each. Building lots are offered for sale at prices representing approximately the cost of the land, plus cost of improvements. A special discount is offered to employes of the Steel Company. Purchasers of lots are required to erect buildings of approved character within eighteen months after purchase. No title passes to purchaser until after the completion of a building.

Buildings for business purposes to the value of approximately $1,500,000 and buildings for residence purposes to the value of approximately $1,000,000 have been erected by outside parties. These estimates do not include many buildings, some of substantial character, erected in Gary south of the Company's First Subdivision, on property not owned by the Gary Land Company.

In addition to the five trunk lines, mentioned under railroad facilities in Gary, is the Chicago, Lake Shore & South Bend Electric Railway Company, connecting Gary with South Bend to the east and with Chicago to the west, through operating arrangements with the surburban lines of the Illinois Central Railroad Company.

The present population of Gary is estimated to be twenty thousand. Two modern public school buildings have been erected in the First Subdivision, one having a capacity for approximately four hundred and fifty pupils, located on the West Side, and one having a capacity for approximately fifteen hundred pupils, located on the East Side.

At the present time Gary has six hotels, five banks and six churches. The Steel Company is erecting a hospital for its employes, the estimated cost of which is $250,000.

The Catholic Church, under the auspices of the Francescan Sisters, is conducting an emergency hospital, and at an early date will commence the erection of a permanent hospital building of sufficient size and capacity to serve a community many times larger than the present population of Gary.

THE RAILROADS SERVING GARY WORKS.

When the plans of the Indiana Steel Company were decided on it was found that the mills would require about one thousand acres in one compact body. In selecting the present site, this could not be obtained without the removal of the Baltimore & Ohio and Chicago, Indiana & Southern Railroads, as they ran diagonally through the center of what was planned as the site for these mills. Negotiations were opened with these railroads for their removal. This brought up the railroad question in this entire Gary district.

Exhaustive surveys and plans were then made on behalf of the United States Steel Corporation. In making these plans the following conditions had to be solved:

First. The best relocation for the railroads affected.

Second. The elimination of railroad grade crossings.

Third. The abolishing of railroad and street grade crossings.

Fourth. The establishment of a large yard to serve the Indiana Steel Company and other industries in this locality, afterward named "Kirk Yard."

Fifth. The locating of interchange yards for all railroads where the freight could be received from and delivered to "Kirk Yard."

Sixth. The most simple and complete switching facilities for serving the different industries.

After repeated conferences with the roads interested, the present plans were approved and work started in May, 1907.

These plans required the relocation of the railroads as follows:

The Baltimore & Ohio from Indiana Harbor to Millers, a distance of ten and one-half miles.

The Chicago, Indiana & Southern from a point one mile east of Indiana Harbor east for a distance of eight and one-half miles.

The Lake Shore & Michigan Southern from Indiana Harbor to a point one mile east of Millers, a distance of eleven and one-half miles.

The Chicago, Lake Shore & Eastern from Cavanaugh to Indiana Harbor and by extension to Kirk Yard, crossing over the Pittsburg, Fort Wayne & Chicago, Wabash, Baltimore & Ohio and Lake Shore & Michigan Southern and connecting with the interchange yard on each of the above roads.

The building of the Gary & Western from a point on the Chicago, Indiana & Southern, one mile east of the Indiana Steel Company plant, to Gibson, on the main line of the Chicago, Indiana & Southern, crossing over the Lake Shore & Michigan Southern, Baltimore & Ohio, old Lake Shore and

Michigan Southern, Chicago, Lake Shore & South Bend electric, and Wabash, Broadway and Madison and First street, and the Pittsburg, Fort Wayne & Chicago, also connecting with the Lake Shore & Michigan Southern at Virginia Street, Gary, thus forming a loop. The Gary & Western forming the east and south leg of the loop and running through the residence district; the Chicago, Indiana & Southern from Gibson to Indiana Harbor forming the west leg of the loop and the Lake Shore & Michigan Southern from Indiana Harbor to Gary forming the north leg of the loop and running through the industrial district; it being planned so that those living along the Gary & Western or Chicago, Indiana & Southern can reach the different industries by quick and cheap transportation.

The Lake Shore & Michigan Southern, Baltimore & Ohio and Chicago, Indiana & Southern new lines were completed and put in operation in July 1908.

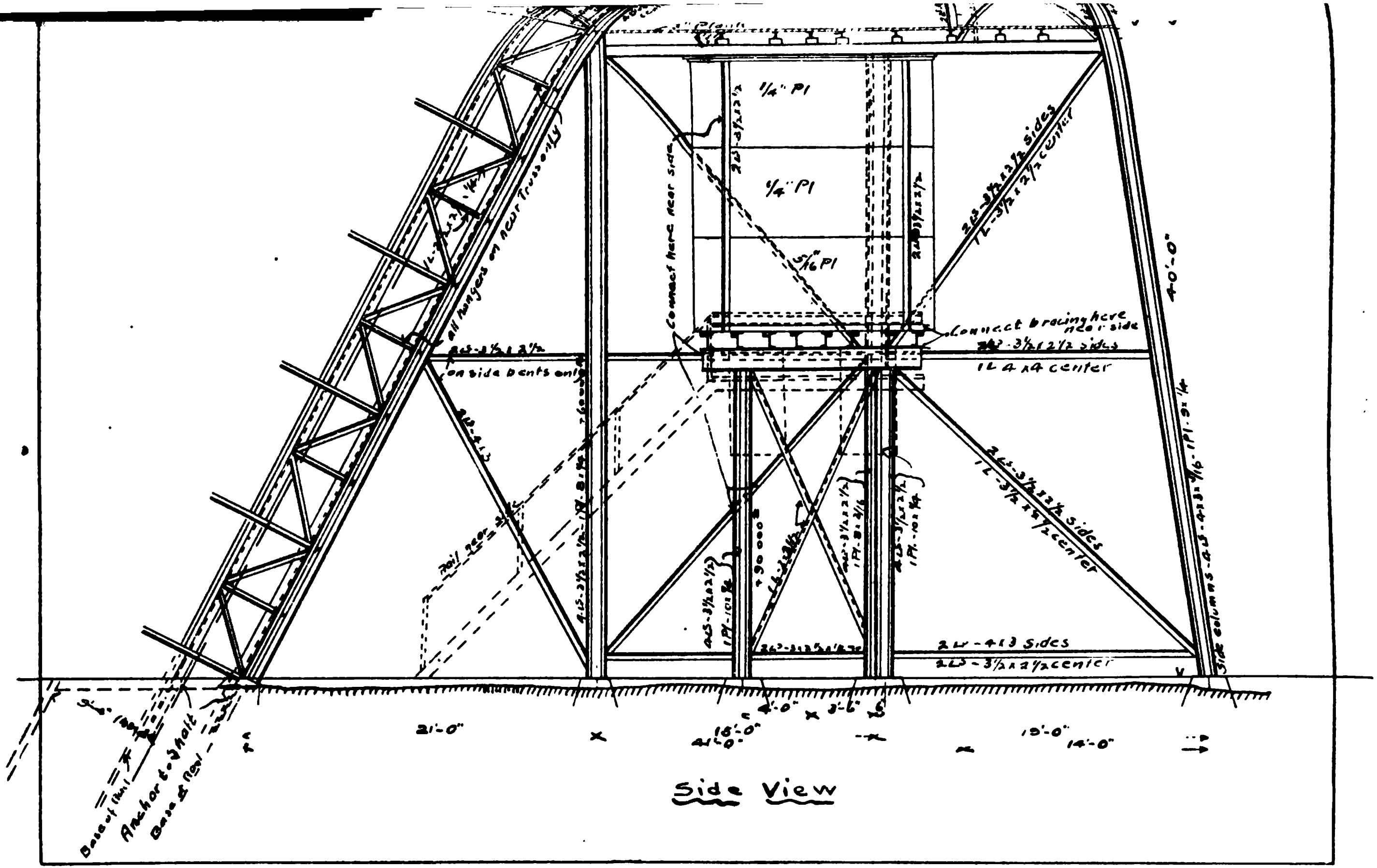
STEEL HEAD FRAME, NO. 4 SHAFT, MONTREAL MINE.

FRANK B. GOODMAN, HURLEY, WIS.

This shaft house was erected by the Wisconsin Bridge & Iron Company in February and March, 1910. The shaft house was designed by the Wisconsin Bridge & Iron Company and is probably the lightest steel shaft house on the Gogebic Range today, and will be a test as to whether the excessive weight that has heretofore been used can be successfully supplanted by a system of bracing. The weight of this shaft house is about fifty-three tons.

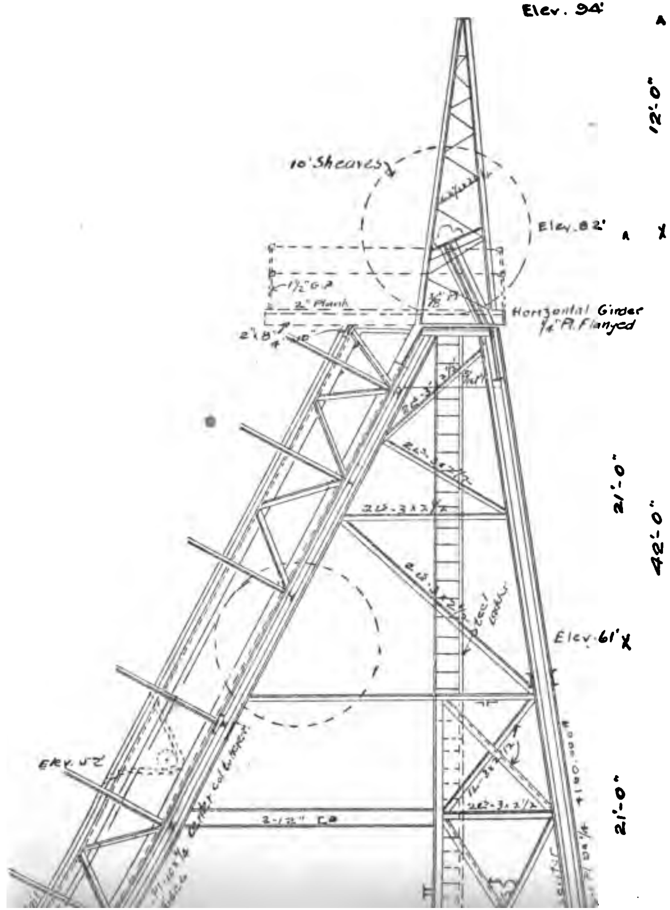
The bin on this shaft house is circular and is the first of its kind used on the Gogebic Range. They are extensively used for copper rock and this will demonstrate whether or not they may be used for iron ore. The live capacity of the bin is one hundred tons. Through this bin will be handled the Lawrence Grade loading into cars through chutes. The Montreal Grade will be loaded in a car and the car run to a bin over the second track where a wooden chute will be constructed to deliver the ore into the railroad cars. The shaft is lined with steel sets of 4″ I-Beams and lagged with 3″ Tamarack plank. There are two skip roads, a cage road, ladder way and pipe compartment. The two skip roads are in the hanging of the shaft with the ladder and pipe ways on the footwall.

The shaft house is 94 feet high at the highest point. The elevation of the center of the sheaves for the skip roads is 82 feet, and the center of the sheave for the cage road is 62 feet. The elevation of the dump is 61 feet and of the landing floor 40 feet.

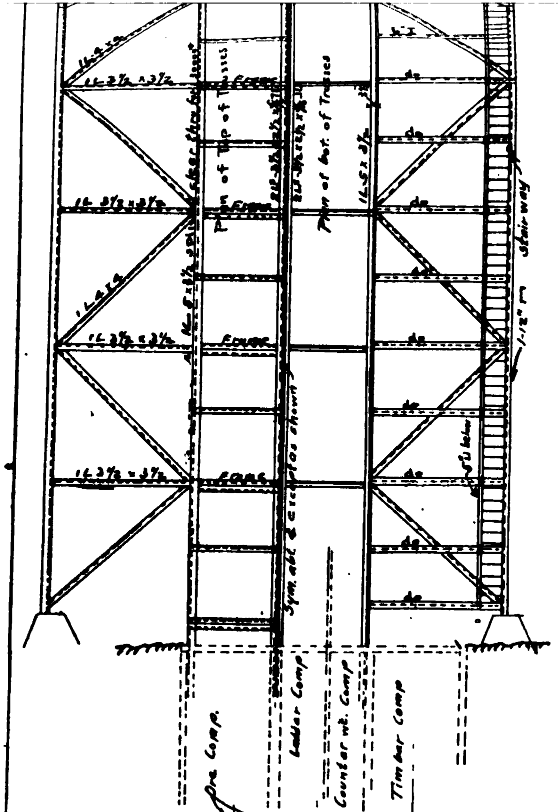


1/4" Pl
1/4" Pl
5/16" Pl
all hangers on near truss only
Connect here near side
Connect bracing here near side
2∠s-3½x2½ sides
1∠ 4x4 center
on side bents only
2∠s-3½x2½ sides
1∠-3½x2½ center
2∠s-3½x2½ sides
1∠-3½x2½x2½ center
2∠-4x3 sides
2∠s-3½x2½ center
+90 000#
40'-0"
21'-0"
10'-0"
14'-0"
Anchor to shaft
Base & Rail

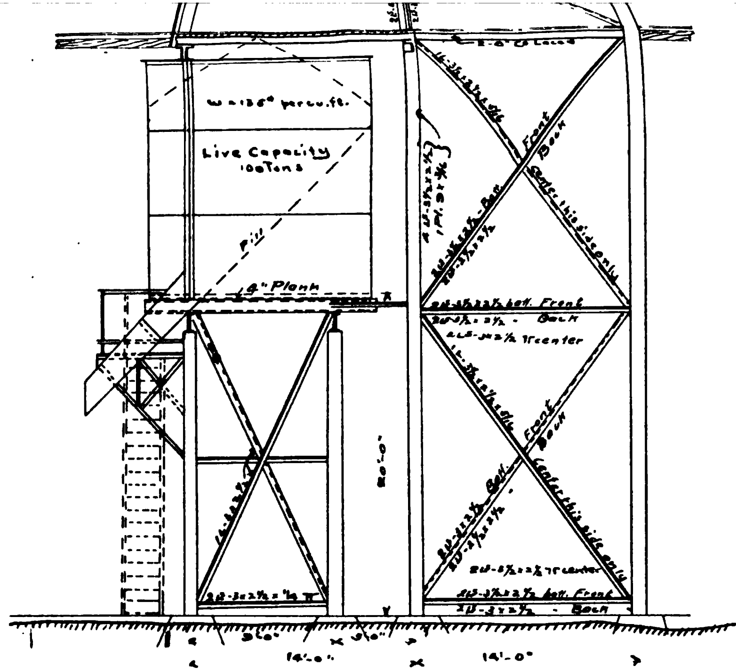
Side View



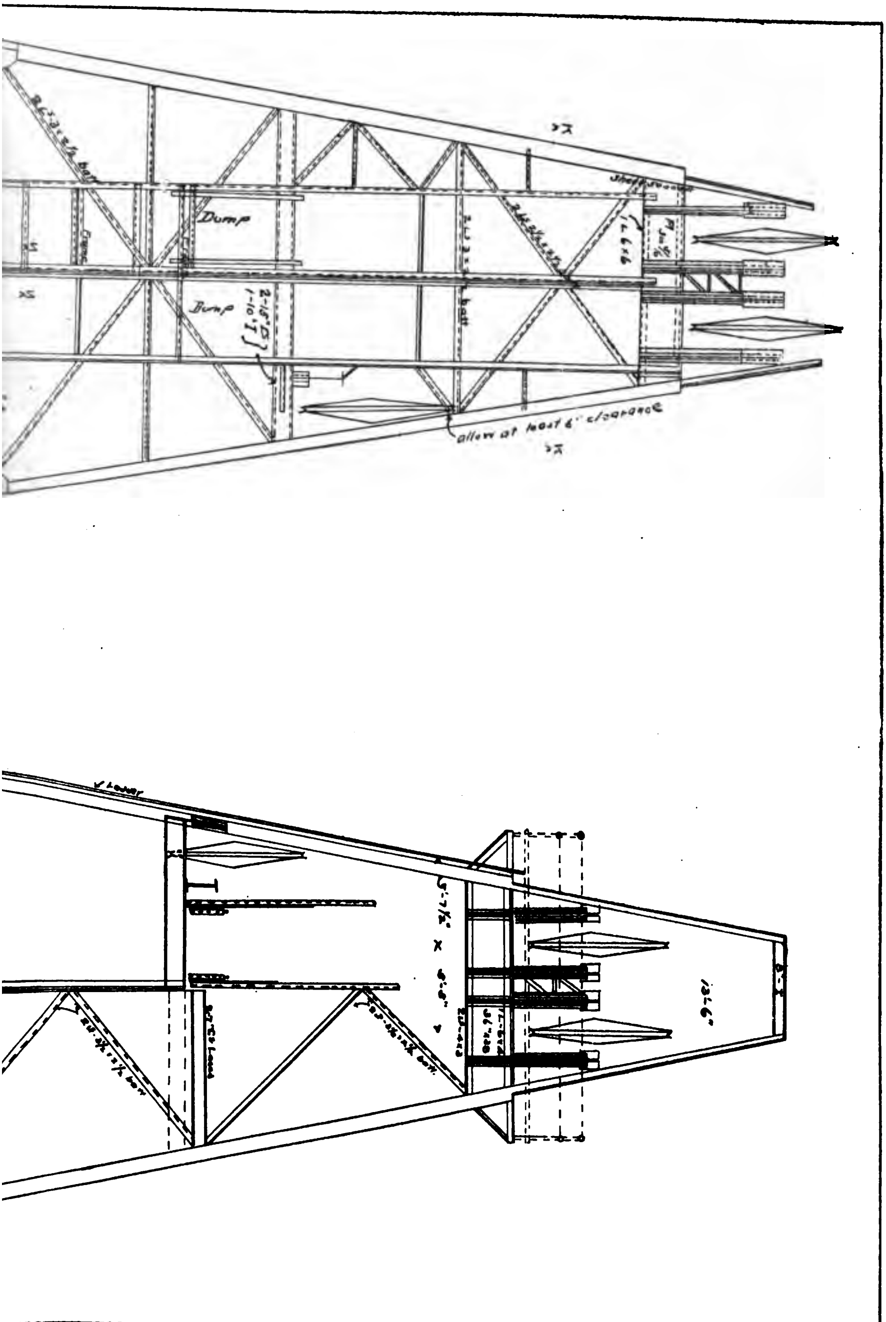
Elev. 94'
12'-0"
10' Sheaves
Elev. 82'
Horizontal Girder
1/4" Pl. Flanged
2" Plank
21'-0"
42'-0"
Elev. 61'
21'-0"

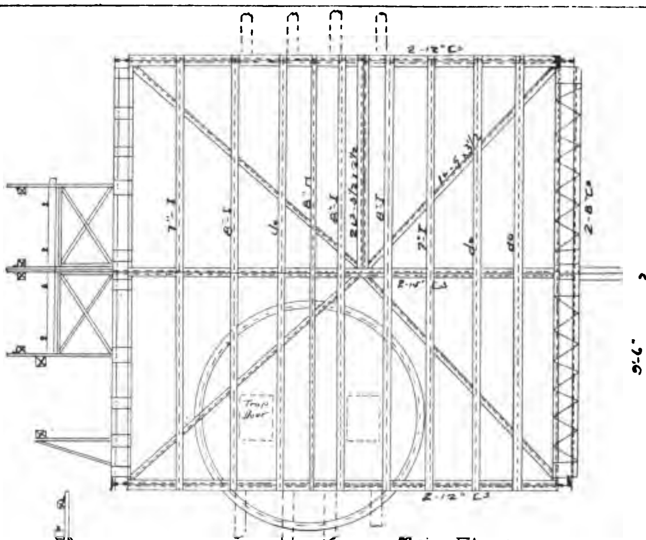


Back View Projected on Plane of Shaft.

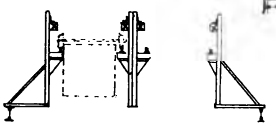


One half interior view   One half Front View

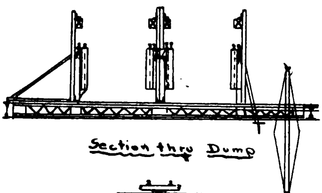

Dump
Dump
allow at least 6" clearance
13'-6"



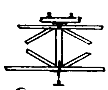
Main Floor



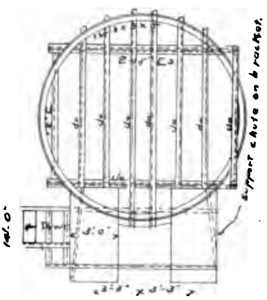
Section - K-K



Section thru Dump

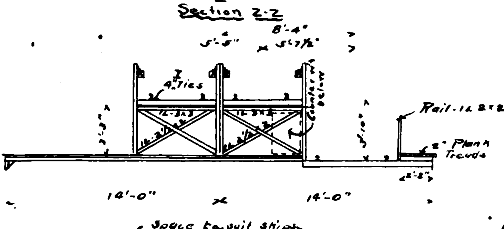


Section Z-Z

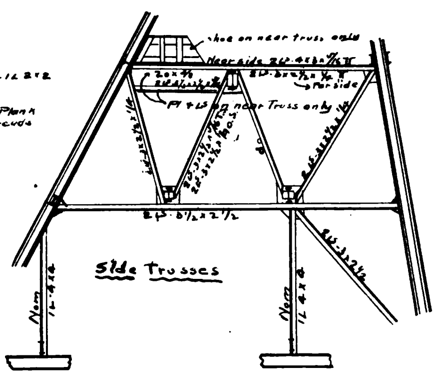


Center of Truck

Bin Floor



Section thru ship tracks below main floor



Side Trusses

The shaft house up to the landing floor is supported by six posts which are built up of 4-3"x4" angle irons ¼" thick with plate 9" wide between, making an H Section. These posts are braced by 2½"x3" angle irons doubled where necessary. On top of these posts are three stringers of same size, carrying steel joists to make landing floor. Posts are bolted to concrete piers, and tied together near piers with double 2½"x3" angle irons. Two 10" channel irons at corners near shaft go from landing floor at inclination of shaft to piers on line with footwall of shaft. Between these two are built from angle irons, the roads for skips and cage and all is braced back against the main posts.

The bin is supported by four independent posts built of 2½"x3" angle irons with 10" plate between, making the H section. On these rest two stringers each made of two 12" channel irons riveted together. These stringers carry eight 10" channel beams, upon which rests the bin. From the landing floor, four posts similar to the main posts go up from each corner to the foundation of the sheaves and same are braced with latticed channel irons and angle irons.

The accompanying sections explain the system of bracing. The sheave wheels used on this shaft house are ten feet in diameter, weigh about 6,000 pounds, made by the Prescott Company.

BIOGRAPHICAL NOTICES.

DR. M. F. M'CABE.

Born 1859, August 26, at Fond du Lac, Wis. Educated in the schools of the same city, taught school from 1879 to 1881. He then studied medicine with a local physician and entered Rush College graduating in February 1885. He came to Bessemer that same year and a few months later to Ironwood, Michigan, where he resided until his death, June 8th, 1910. He was surgeon for the Aurora and Newport mines from 1886 to 1901 and in such capacity met and knew large numbers of the men connected with the mining interests on the Gogebic Range.

FRANK P. MILLS, SR.

Born in Yates County, N. Y., in 1827. He accompanied Robert Nelson to Ishpeming in 1858, and when Mr. Nelson assumed charge of the Cleveland property Mr. Mills became his assistant. In this position he remained for three years leaving to engage in the mercantile business with Mr. Neeson in Marquette. His wife died in Marquette in 1864 and he returned to Ishpeming in May, 1865, where he was placed in general charge of the Cleveland properties. Up to that year only a few pits had been opened and not more than 50,000 tons had been shipped during any one year.

Among the mines opened by Mr. Mills were the Larry Gent Pit, the Furde Pit, the School House mine and the pit on the Marquette side. The first shaft in the Cleveland properties was sunk in the Larry Gent Pit under his supervision. He remained in charge of the Cleveland properties until about 1885 when he resigned and was succeeded by D. H. Bacon.

He was Ishpeming's first Mayor being elected to that office in 1873 when the city was organized. He was admired and respected by employers and friends for his integrity and sterling character. His death occurred July 7th, 1910 at Cedar Edge, Colorado.

CHARLES H. HALL.

Charles H. Hall was born in Bloomingburg, N. Y., September 20th, 1828, and died at Maitland, Florida, March 9th, 1910. After receiving a common school education he went to Connecticut and there learned the machinist trade, and in 1865 was Superintendent of the Bullard & Parsons Machine Works at Hartford.

In the summer of 1867 he visited the Lake Superior region and built the dam on the Carp River above the falls at Deer Lake where some Connecticut capitalists were building a blast furnace. In the spring of 1868 he took charge of the Deer Lake Iron Company's affairs. The furnace was successfully blown in later in that year, using specular ores from the "New York" mine, this was before soft hematites had been used in any of the Lake Superior furnaces. In 1874 Mr. Hall was appointed agent of the Lake Superior Iron Company. This was at a time of great business depression and the affairs of the Company were involved in many difficulties. The employees were being paid in "Iron money." When Mr. Hall took charge of the Company's interest practically all mining in Marquette County was carried on in open pits. He soon introduced a system of underground mining and was one of the first to use power rock drills, the caving system of mining soft hematite, the loading of ore with steam shovels, and diamond drills for exploring, having during his administration drilled something over 200,000 feet of diamond drill holes. At his suggestion the company was possibly the first to install a fully equipped machine shop at a mine in the Iron District.

During his residence in Marquette County he was elected a County Supervisor a number of times, serving as Chairman one or two years. He installed the first system of water works in Ishpeming and was twice elected Mayor of the city. In 1883 he organized the Ishpeming National Bank (now the Miners' National) and acted as president during his residence in Ishpeming. On his retirement from business in 1897 he took up his residence at Evanston, Illinois, having his winter home at Maitland, Florida.

JACOB HOUGHTON.

Jacob Houghton born in Fredinia, Chautauqua County, New York, May 28, 1827, youngest child of Judge Jacob and Lydia Douglas Houghton. He attended the Fredinia academy, showing a great taste for Latin, Greek and Mathematics. In 1842 he came to Detroit, Michigan, where his brother, the late Dr. Douglas Houghton resided. Jacob Houghton attended the branch university and was a member of the Alpha Delta Phi fraternity.

In 1844 Jacob Houghton went on the Government survey of the mineral region of Lake Superior and it was while on this trip that the first iron ore in Michigan was discovered, Judge Burt of Rowes being in charge of the party. The summer of 1845 also found him a member of the survey. From 1846-1850 Jacob Houghton was employed in surveying and laying the tracks for the Michigan Central, Michigan Southern, Detroit and Milwaukee and New York and Harlem railroads. In 1850 he returned to Detroit and from 1850-1852 was on the Government survey of the Straits of Mackinaw.

In 1852 he was appointed engineer and Superintendent of the Detroit Water Works. He laid the first iron water pipes in the city, replacing the old ones of tamarack logs. In 1860 he resigned from the employ of the water works and moved to Lake Superior, where he was superintendent and general manager of the Bay State Mine and the Menard and Pontiac Mine. In 1867 he returned to Detroit and went into partnership with a man by the name of Shaw, in what was called the edge tool business. This not proving successful in 1870 he returned to Lake Superior, surveyed and built the Marquette, Houghton and Ontonagon Railroad, now a part of the Duluth, South Shore & Atlantic system.

In 1875, he became manager and superintendent of the Michigamme mine at Michigamme in Marquette County, Michigan. In 1878 he moved to Colorado and became manager of the Moose mine at Dudley, in Park County. In 1880 he moved to Leadville and for several years was manager of the Iron Silver mine, resigning to become president of the Synchibal Mining Co. which operated on leased and purchased land in Leadville. In 1890 Mr. Houghton returned to Detroit and since then has spent several summers on Isle Royale, Lake Superior, exploring for copper, having interests in the Isle Royale Land Corporation, Limited, an English Company.

Jacob Houghton married Theodosia Petite Gilbert, daughter of the late Shadrack and Mary Stiad Gilbert of Detroit. The ceremony was performed in Detroit on April 28, 1853. Six children were born of this union, five of whom are living: Mrs. Geo. Singleton, Minneapolis, Minn.; Phillip S. Houghton, Grand Forks, N. D.; Douglas G. Houghton, Leadville, Col., and Misses Sara F. and Annie G. Houghton of Detroit, Mich. Another daughter, Mrs. Edward L. Linquand, died in Florida some years ago. Mrs. Houghton died February 6, 1898. He died Dec. 29, 1903, at Detroit, Mich.

Gilbert D. Johnson.

Born at Enfield, N. H., July 2nd, 1819. When 10 years of age the family moved to Boonville, N. Y., and when 19 years old he moved to Kingston, N. Y., where he engaged in the mining of hydraulic cement rock.

In 1841 he married Emeline Diamond. Moving to Sandusky, Ohio, in 1853 he continued mining cement rock and while in this work he was engaged by the Lake Superior Iron Company to take charge of the property acquired by them in Marquette County. Moving to Northern Michigan in 1857 he was in charge of the Lake Superior Mine when the first earth was removed from the old open pit. The waste material from the openings made were dumped into the nearby swamps and later on the land thus made was platted by Robert Nelson into the town of Ishpeming.

When he began work in the Lake Superior mine his force consisted of 6 men, T. Cameron, Simon Canfield, his son James, "Scottie" Welsh and two others. He and his men assisted in erecting the first building in Ishpeming, a boarding house, that stood for many years. When living up stairs in this new building he saw wolves walking around on the loose lumber below during a moonlight night they having come in from the nearby timber.

In 1857 Mr. Johnson mined and shipped 300 tons of ore which was sent to Marquette in the fall after the completion of the plank road to that place. In the spring of 1858 Captain Johnson employed Thos. Flannigan and Captain John McEncroe, the present Captain of the Lake Superior mine, and 20 others to work in what is now known as the McEncroe pit. During this year they mined and shipped 4,685 tons of ore. In 1875 he severed his connection with the Lake Superior Mining Company and engaged in silver mining in Utah remaining there until 1882, after which he was interested in several mining ventures in Canada and Colorado. The high altitudes of Colorado affecting his health he later moved to the home of his daughter Mrs. S. S. Scoville, Chicago. He died on a visit to Cripple Creek, June 26th, 1893. He was the first President of the Village of Ishpeming.

A. P. Swineford.

Mr. Swineford was a native of Ohio, but from the day that he became a citizen of Michigan the State of his adoption had the full benefit of his loyal devotion to its interests, of his great abilities and his wonderful energy in a variety of public positions, and in a semi-public capacity as a publisher and editor, until he was appointed Governor of Alaska by President Cleveland in 1885.

He came to Michigan in 1867, locating at Negaunee, in Marquette county, where he engaged in the publication of a newspaper. Some three years later he removed to Marquette taking over the paper then published in that city, which he rechristened "The Mining Journal," by which name it has since been known.

Shortly after he acquired ownership of The Mining Journal he issued a "Review of the Copper, Iron, Silver, Slate and other Material Interests of the South Shore of Lake Superior," which was a concise and comprehensive setting forth of their importance and promise. This publication was continued for years as an "Annual Review," of these interests, special attention being given to the iron and copper mining industries, and its value to these obtained prompt recognition. He was chosen representative in the state legislature of 1871-2 from the district comprising the counties of Marquette, Delta, Menominee and Schoolcraft. In 1876 Mr. Swineford published his "Mineral Resources of Lake Superior," a more ambitious publication than his "Annual Review" of the iron and copper mines, etc.

In 1883 Mr. Swineford was appointed Commissioner of Mineral Statistics for Michigan, serving in that capacity until he was appointed Governor of the territory of Alaska by President Cleveland in 1885, when he removed from Michigan to assume charge of the important trust confided to him. Here again his vigorous pen and eloquent tongue were enlisted in a great and patriotic work, that of bringing to attention of the Government at Washington the vast industrial and commercial value of Alaska, and the necessity for providing that remote territory with a system of government more suited to its needs and better calculated to promote its advancement than that under which it was then making a halting and laborious progress. Through appeals to congress and articles published in the press of the states he kept up the fight for legislation to meet the needs of his jurisdiction. Attention was at last attracted to the far-away territory and presently capitalists came to regard it as a region where there were inviting opportunities for investment. He made a tour of the territory for the purposes of observation and examination, which covered every penetrable section of it, and embodies the results of this great and arduous undertaking in a volume entitled "Alaska, its History Climate and Natural Resources" which gave to the people of the United States a comprehensive idea of the great prospective value to the nation of that immense territory. In closing his work on the territory Governor Swineford said: "In her vast mountain ranges are stored away not alone gold and silver, but nearly every other kind of mineral in the least adapted to the wants of commerce or the uses of mankind. With her wealth of precious metals, her great seams of coal, mountains of iron and veins of copper, her illimitable forests, wide areas of grazing lands, fisheries from which the world's millions might be fed, to say nothing of the possibility, even probability in the way of agricultural and horticultural development, who shall undertake to either definitely estimate or fix a limit to the value of Alaska's undeveloped resources?"

After expiration of his term as governor of Alaska Mr. Swineford returned to the States and was for a time connected with the Interior Department of the Federal Government as a special agent. But he showed his faith in the future of Alaska by returning to the territory and interesting himself in mining and other ventures. He also published a paper at Kechikan for several years, in the conduct of which he displayed his old-time vigor and versatility as a writer. After a life of abounding activity and large achievement he has gone to his rest, but he will be long remembered in the Lake Superior region, with whose early development he was so intimately identified, and to which he so greatly contributed.

Mr. Swineford died at his home in Alaska, October 26th, 1909.

PAST OFFICERS.

PRESIDENTS.

Nelson P. Hulst	1893
J. Parke Channing	1894
John Duncan	1895
William G. Mather	1896
William Kelly	1898
Graham Pope	1900
W. J. Olcott	1901
Walter Fitch	1902
George H. Abeel	1903
O. C. Davidson	1904
James MacNaughton	1905
Thomas F. Cole	1906
Murray M. Duncan	1908
D. E. Sutherland	1909

(No meetings were held in 1897, 1899 and 1907.)

VICE PRESIDENTS.

1893.

John T. Jones.		Graham Pope.
F. P. Mills.	J. Parke Channing.	M. W. Burt.

1894.

John T. Jones.		Graham Pope.
F. P. Mills.	R. A. Parker.	W. J. Olcott.

1895.

F. McM. Stanton.		Per Larsson.
Geo. A. Newett.	R. A. Parker.	W. J. Olcott.

1896.

F. McM. Stanton.		Per Larsson.
Geo. A. Newett.	J. F. Armstrong.	Geo. H. Abeel.

1898.

E. F. Brown.		Walter Fitch.
James B. Cooper.	Ed. Ball.	Geo. H. Abeel.

1900.

O. C. Davidson.		J. H. McLean.
T. F. Cole.	M. M. Duncan.	F. W. Denton.

1901.

J. H. McLean.		F. W. Denton.
M. M. Duncan.	Nelson P. Hulst.	William Kelly.

1902.

William Kelly.		H. F. Ellard.
Nelson P. Hulst.	Fred Smith.	Wm. H. Johnston.

	1903.	
H. F. Ellard. Fred Smith.	James B. Cooper.	Wm. H. Johnston. John H. McLean.
	1904.	
M. M. Duncan. Fred M. Prescott.	F. W. McNair.	John H. McLean. James B. Cooper.
	1905.	
M. M. Duncan. Fred. M. Prescott.	F. W. McNair.	J. M. Longyear. F. W. Denton.
	1906.	
M. M. Duncan. J. M. Longyear.	Fred M. Prescott.	F. W. McNair. F. W. Denton.
	1908.	
J. M. Longyear. F. W. Denton.	David T. Morgan.	D. E. Sutherland. Norman W. Haire.
	1909.	
W. J. Richards. Charles Trezona.	J. H. Rough.	John M. Bush. Frederick W. Sperr.

MANAGERS.

	1893.	
John Duncan. Walter Fitch.	William Kelly.	James MacNaughton. Charles Munger.
	1894.	
Walter Fitch. John Duncan.	M. E. Wadsworth.	C. M. Boss. O. C. Davidson.
	1895.	
F. P. Mills. Ed. Ball.	M. E. Wadsworth.	C. M. Boss. O. C. Davidson.
	1896.	
F. P. Mills. Ed. Ball.	C. H. Munger.	Graham Pope. William Kelly.
	1898.	
M. M. Duncan. J. D. Gilchrist.	T. F. Cole.	Graham Pope. O. C. Davidson.
	1900.	
E. F. Brown. Ed. Ball.	James B. Cooper.	Walter Fitch. George H. Abeel.
	1901.	
James B. Cooper. James MacNaughton.	(One Vacancy.)	James Clancey. J. L. Greatsinger.
	1902.	
James Clancey. J. L. Greatsinger.	Amos Shpehard.	Graham Pope. T. F. Cole.
	1903.	
Graham Pope. Amos Shephard.	Wm. J. Richards.	T. F. Cole. John McDowell.
	1904.	
John McDowell. Wm. J. Richards.	John C. Greenway.	William Kelly. H. B. Sturtevant.

1905.

John C. Greenway. William Kelly. H. B. Sturtevant.
Jas. R. Thompson. Felix A. Vogel.

1908.

James R. Thompson. John C. Greenway. J. Ward Amberg.
Felix A. Vogel. Pentecost Mitchell.

1909.

F. E. Keese. L. M. Hardenburg. Charles E. Lawrence.
W. J. Uren. Wm. J. West.

TREASURERS.

C. M. Boss 1893
A. C. Lane 1894
Geo. D. Swift 1895-1896
A. J. Yungbluth 1898-1900
Geo. H. Abeel 1901-1902
E. W. Hopkins ....1903-....

SECRETARIES.

F. W. Denton 1893-1896
F. W. Denton and F. W. Sperr....................1898
F. W. Sperr 1900
A. J. Yungbluth ....1901-....

LIST OF PUBLICATIONS RECEIVED BY THE INSTITUTE.

American Institute of Mining Engineers, 99 John St., New York City.

Canadian Mining Institute, Ottawa.

American Society of Civil Engineers, 220 W. 57th St., New York City.

Institution of Mining Engineers, Neville Hall, Newcastle-upon-Tyne, England.

Massachusetts Institute of Technology, Boston, Mass.

Chemical, Metallurgical and Mining Society of South Africa, Johannesburg, S. A.

Western Society of Engineers, 1734-41 Monadnock Block, Chicago.

The Mining Society of Nova Scotia, Halifax, N. S.

Canadian Society of Civil Engineers, Montreal.

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

State Bureau of Mines, Colorado, Denver, Colo.

Stahl and Eisen, Dusseldorf, Germany, Jacobistrasse 5.

Reports of the U. S. Geological Survey, Washington, D. C.

Geological Survey of New South Wales, Sydney, N. S. W.

Geological Survey of Ohio State University, Columbus, O.

The Mexican Mining Journal, Mexico City, Mexico.

Mines and Mining, 1824 Curtis St., Denver, Colo.

Engineering-Contracting, 355 Dearborn St., Chicago, Ills.

Mining Science, Denver, Colo.

Mining & Scientific Press, 667 Howard St., San Francisco, Cal.

University of Oregon, Library, Eugene, Oregon.

Case School of Applied Science, Department of Mining & Metallurgy, Cleveland, Ohio.

University of Illinois, Exchange Department, Urbana, Ills.

University of Missouri, Columbia, Mo.

Iowa State College, Ames, Iowa.